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Report 236

Physical Volcanology and Stratigraphy of the

Confederation Lake Area

District of Kenora (Patricia Portion)

by
P. C. Thurston

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FOREWORD

CONFEDERATION LAKE AREA

The Ontario Geological Survey began mapping in the Uchi-Confederation greenstone belt shortly after the discovery of the Selco Incorporated Cu-Zn-Ag orebody at Confederation Lake in 1969. Detailed mapping of 14 townships and 100 square miles of unsubdivided territory and 1:50 000 scale mapping of the Birch Lake area to the north followed through to 1978. This report describes a synoptic project covering 375 square miles in the southern part of the area.

The report describes the stratigraphy of three cycles of mafic to felsic volcanism, including geochronological data, and a paleovolcanological reconstruction. Geochemical work done as part of this synoptic project is described in a separate Ontario Geological Survey publication.

V.G. Milne
Director
Ontario Geological Survey

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(back pocket)

Map 2498 (coloured)-Confederation Lake Area, District of Kenora (Patricia Portion).
Scale 1:50 000

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(back pocket)

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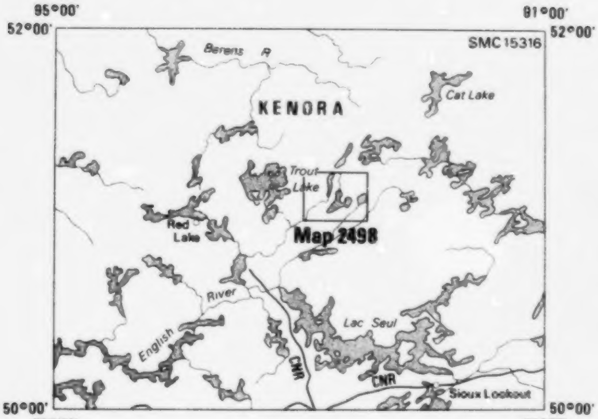
95°00'
91°00'
52°00'
52°00'
SMC 15316
Berens R
KENORA
Cat Lake
Trout Lake
Red Lake
Map 2498
River
English
Lac Seul
CNR
CNR
Sioux Lookout
50°00'
50°00'
95°00'
91°00'

Figure 1–Key map showing location of Confederation Lake area.

ABSTRACT

Archean volcanic rocks in the Confederation Lake area, northwestern Ontario, are in three mafic to felsic cycles collectively 8500 to 11 240 m thick. Each cycle begins with pillowed basalt and andesite flows and is capped by andesitic and rhyolitic pyroclastic rocks and minor flows. Cycle I is believed to be entirely subaqueous inasmuch as it is overlain by 90 m of limestone. Cycle II has basal pillowed basalt flows and andesitic to rhyolitic pyroclastic rocks locally overlain by 100 to 150 m of rhyolite tuff with intensely welded fragments. The environment of deposition of this unit appears to have been subaerial. Cycle II is overlain by stromatolitic limestone and pillowed basalt flows at the base of Cycle III. The remainder of Cycle III consists of dacitic pyroclastic rocks, rhyolitic flows, pyroclastic rocks, and coeval hypabyssal intrusions.

Cycle I rhyolites are 2959 Ma old, Cycle II rhyolites are 2794 Ma, and Cycle III rhyolites are 2739 Ma old according to U-Pb age determinations on zircons. These time periods are in accord with observed periodicity in young volcanic terranes.

Cycle I is interpreted as a platform upon which Cycle II was deposited in the early stages of caldera development. Cycle III is the central graben of the caldera and is the product of resurgent volcanism, hypabyssal intrusions, and late stage hydrothermal activity which formed the Cu-Zn-Ag massive sulphide body of South Bay Mine. The tectonic scheme favoured on the basis of structural, lithologic, and chemical parameters is that of a marginal basin behind a volcanic arc.

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If the reader wishes to convert imperial units to SI (metric) units or SI units to imperial units the following multipliers should be used:

CONVERSION FROM SI TO IMPERIAL			**CONVERSION FROM IMPERIAL TO SI**		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
LENGTH					
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709 7	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
AREA					
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
VOLUME					
1 cm^3	0.061 02	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.308 0	cubic yards	1 cubic yard	0.764 555	m^3
CAPACITY					
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
MASS					
1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 908 8**	t
CONCENTRATION					
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

1 ounce (troy)/ton (short)	20.0	pennyweights/ton (short)
1 pennyweight/ton (short)	0.05	ounce (troy)/ton (short)

NOTE–Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries published by The Mining Association of Canada in co-operation with the Coal Association of Canada.

Physical Volcanology and Stratigraphy

# of the

Confederation Lake Area

District of Kenora

(Patricia Portion)

by

P.C. Thurston[1]

INTRODUCTION

This report examines the general geology, volcanology, stratigraphy, and temporal aspects of cyclical volcanism, in the Confederation Lake area, Ontario (see Figure 2). In this area, metavolcanics and less voluminous metasediments of regional greenschist rank are in three cycles, each consisting of a mafic base grading to a felsic top. The cycles are not underlain by ultramafic volcanic rocks, and appear to be in the "greenstone group' of C.R. Anhaeusser (1971, p.61). There are several concentrations of massive base metal sulphide minerals and one producing mine within the uppermost cycle. Gold was produced from 1938 to 1942 from chert horizons and quartz vein systems in volcanic rocks of the middle cycle.

The purpose of this report is to characterize the three volcanic cycles in terms of:

1. regional stratigraphy
2. style of volcanism
3. petrography of the metavolcanics
4. temporal evolution of the volcanic sequence.

---

[1] Supervising Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto. Approved for publication by the Chief Geologist, March 4, 1982. This report is published with the permission of V.G. Milne, Director, Ontario Geological Survey.

Present Geological Survey

Mapping consisted of check traverses at arbitrary intervals to validate previous mapping, plus traversing at 0.8 km intervals in Skinner Township and other poorly known parts of the area. Data were recorded on acetate overlays for 1:15 000 airphotos supplied by the Ministry of Natural Resources Air Photo Library, and later generalized, reduced, and plotted on base maps at 1 inch to 1 mile supplied by the Cartography Section, Division of Lands, Ontario, Ministry of Natural Resources.

In 1975, the author participated in detailed mapping of Honeywell and McNaughton Townships (Johns and Thurston 1975) and began a systematic compilation and reinterpretation of the southern part of the Birch-Uchi Belt, called the Confederation Lake area (Thurston 1975, 1976; Thurston and Jackson 1978).

Detailed mapping of Earngey, Birkett, Agnew, and Costello Townships was done by the author and assistants in 1973 and 1974 (Thurston *et al.* 1974, 1975a, b, c). Detailed mapping of Honeywell and McNaughton Townships was carried out with the author's supervision and active participation in 1975 (Johns and Thurston 1975) while the author began mapping and compiling the remainder of the area at a regional scale.

Samples were collected during the summers of 1973, 1974, 1975, 1976, and 1977. Mineralogy and textures were examined in over 400 thin sections; X-ray diffraction was used in some instances for determining mineralogy.

A compilation of all previous chemical analyses was made to check rock identification made in the field. This compilation of rock chemistry and a number of new analyses made by the Geoscience Research Laboratory, Ontario Geological Survey, and the author are reported separately.

Location, Access, and Physiography

The Confederation Lake area is about 100 km east-northeast of the Town of Red Lake, District of Kenora (Patricia Portion), northwestern Ontario. It is between 51°00′ and 51°15′ N Latitudes and 92°30′ and 93°00′ W Longitudes, within the Trout Lake (52N) topographic map-sheet.

Access to Confederation Lake is by road to the South Bay Mine of Selco Incorporated at the narrows of Confederation Lake. This road branches from Highway 105 at Ear Falls south of Red Lake (Figure 2). Access to most other lakes in the area is by float-equipped aircraft available for charter at Red Lake or Ear Falls. There are three tourist lodges in the area.

The area has a maximum relief of 90 m with a few prominent hills, but in general the topography is subdued, typical of this part of the Canadian Shield. The amount of exposure is variable, but typically constitutes 30 to 40 percent of the area; most bedrock is beneath 10 to 15 cm of moss. Lithology and structure affect lake distribution. Leg Lake, Uchi Lake, Woman Lake, and Narrow Lake are elongate parallel to strike and Leg, Uchi, and Fly Lakes are along major faults. Drainage is via the Uchi and Wenasaga Rivers to Lac Seul and Lake Winnipeg.

Previous Work

In 1893, D.B. Dowling (1896) did a geological reconnaissance for the Geological Survey of Canada which took him through Confederation and Fly Lakes. E.M. Burwash (1920) travelled the North Bay of Confederation Lake and the Wenasaga River and J.W. Greig (1928) mapped in the vicinity of Woman and Narrow Lakes. Additional work by the Ontario Department of Mines includes that of E.L. Bruce (1929), W.D. Harding (1936), J.E. Thomson (1939) and G.D. Furse (1934). In 1938, J.D. Bateman (1940b,c) mapped in the eastern part of the area at a scale of 1 inch to 1 mile and studied the gold deposits which he suggested were concentrated about granites.

The map area is part of the region included in a reconnaissance survey carried out by the Geological Survey of Canada from 1959 to 1961 (Duffell *et al.* 1963; Prest 1963; Donaldson and Jackson 1969). A variety of geochemical studies based on material collected during the above survey are reported upon by R.H.C. Holman (1963), R.L. Moxham (1965), and R.F. Emslie and R.H.C. Holman (1966). A.M. Goodwin (1967) did pioneering whole-rock chemical analyses and stratigraphic studies in the area.

Upon discovery of the orebody at the South Bay Mine in 1968, the Ontario Department of Mines started detailed mapping of the Birch-Uchi Belt, first by A.P. Pryslak (1970a,b; 1971a,b; 1972a,b) and later by the author (Thurston *et al.* 1974; 1975a,b,c; Thurston 1978). G.D. Pollock *et al.* (1972), J.S. Auston (1969), and J.F. Touborg (1973) described the geology of the South Bay Mine and a limited area around it.

Previous whole-rock chemical analyses and their application in mineral exploration is the subject of P.H. Davenport's work (1972) and that of V.J. Sopuck (1977). P.K. Seccombe (1973) examined sulphur isotopes and trace elements in the South Bay Mine area. V.J. Sopuck (1971), B.C. Asbury (1975), J. Lalor (1970), and G. Koschel (1975) studied various aspects of the area in Master theses and R.M. Falls (1974), D.J. Birnie (1972), J.E. Barclay (1976), D.F. Baker (1975), T. McAuley (1973), M. Berezowsky (1972), and S.E. Savory (1976) conducted relatively detailed studies in B.Sc. theses.

Barlow *et al.* (1976) performed a gravity survey which includes the map area. The author, in conjunction with F.W. Breaks of the Ontario Division of Mines (Thurston and Breaks 1978), has suggested large-scale thrusting along the Uchi-English River Subprovince boundary south of the map area based on a combination of geological and geophysical evidence.

Acknowledgments

M. Raudsepp, B.C. Wilson, W. Waychison, R.M. Falls, and M.C. Jackson mapped parts of the area. Junior assistants in the various years were: T. Carter, R. Falls, G.R. Davidson, J.M. Hill, J. Ernsting, D.F. Baker, B.C. Anderson, C.M. Ware, H. Christmann, L. Leonard, and D. Brisbin. Numerous junior assistants provided logistical support and several B.Sc. theses which helped with understanding parts of the area. The staff of the South Bay Mine, particularly J. Wan, geologist, and D. Thomson, manager, helped with logistics and accommodation at various times.

Drafting has been done by Barbara Moore, Linda Christiansen, and Jim Foster. Typing of the final version was done by Jennifer John and Anna Branicky.

Logistical help was provided by Mr. and Mrs. R. Schwarz of Uchi Lake and Mr. and Mrs. K. Koezur of Birch Lake. Green Airways at Red Lake provided excellent air service.

GENERAL GEOLOGY

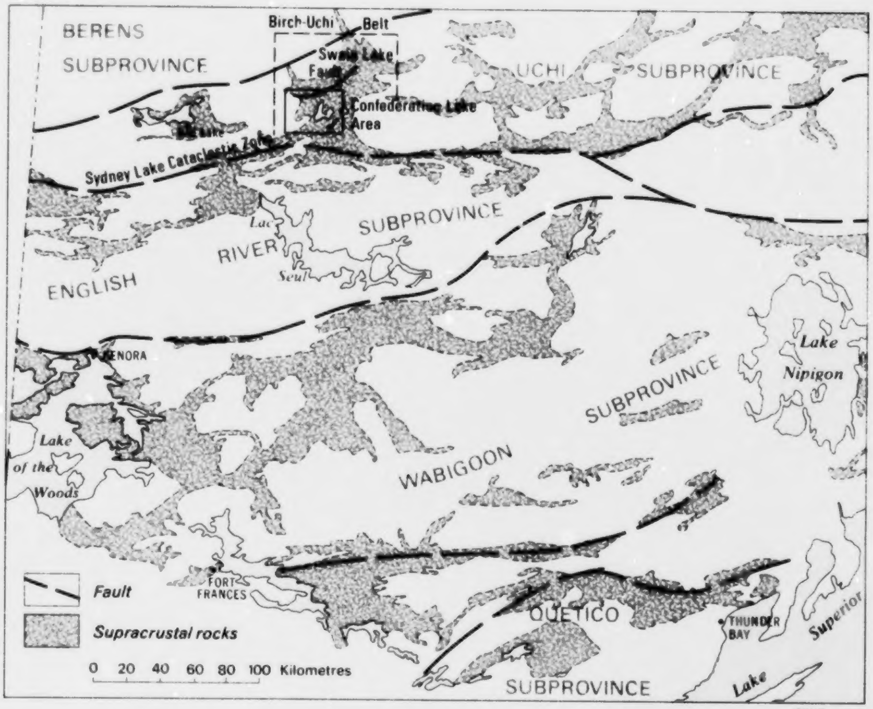
The Confederation Lake area is within the Uchi Subprovince of the Superior Province of the Canadian Shield (Ayres *et al.* 1971) and includes the southern part of the Birch-Uchi Belt of north-trending metavolcanics and metasediments (Goodwin 1967), 32 km wide by 84 km long (Figure 2). The Swain Lake Fault (Goodwin 1967) forms the area's northern border, across which the rocks change in strike and complexity (Thurston 1977). The area is bounded to the south by the English River Subprovince, which has a greater proportion of metasediments and anatectically derived granitic rocks (Breaks *et al.* 1974). The area is bounded to the east and west by granitic batholiths of regional dimension. As all supracrustal rocks described here are metamorphosed to greenschist facies of regional metamorphism, the prefix "meta' will henceforth be understood to apply to all rock types.

Goodwin recognized two cycles of mafic to felsic volcanism, here termed Cycles II and III, and Pryslak later (1971a,b) identified Cycle I, the lowest cycle. Cycle I trends north and dips east with the basalts at its base extending northward from Bear Lake to the east of Corless Lake (see map, back pocket). The upper part of the cycle terminates at the east end of Spot Lake. The east part of Cycle I is exposed on the axis of an anticline at Leg Lake. The basalts at the base of Cycle II trend north and dip east at the south end of Woman Lake and continue through Quartz Lake where they have a more eastward strike, persisting to the west end of Narrow Lake. East of the synclinorial axis, basalts of Cycle II extend from Agnew Lake to the Bear Lake Fault in Neepawa Bay of Uchi Lake. Rocks of Cycle III underlie the area between Lost Bay of Confederation Lake and the main part of that lake.

The area has folds with nearly vertical limbs. The trace of the axial plane of a regional synclinorium trends south through the geographical centre of the area flanked, 13 km to the east, by a regional anticlinorium (Figure 4). West of the synclinorial axis, the rocks are a homoclinal succession, facing east. East of the synclinorial axis, west facings persist only part way through the sequence, giving way to many local reversals of dip and succeeded, in the area of Leg Lake, by a regional anticlinorium.

The thickness of the metavolcanic-metasedimentary rock sequence is difficult to determine because of structural complexities east of the synclinorial axis, however, Thurston (1977) (Figure 4) estimated a total thickness of 8500 m, and Goodwin (1967, p.85) has estimated a thickness of 7400 m west of the synclinorial axis (see map, back pocket).

For ease of description, formational nomenclature is used in an informal


BERENS SUBPROVINCE
Birch-Uchi Belt
Swain Lake Fault
Confederation Lake Area
UCHI SUBPROVINCE
Sydney Lake Cataclastic Zone
ENGLISH RIVER SUBPROVINCE
Lac Seul
KENORA
Lake of the Woods
WABIGOON SUBPROVINCE
Lake Nipigon
FORT FRANCES
QUETICO SUBPROVINCE
THUNDER BAY
Lake Superior
Fault
Supracrustal rocks
0 20 40 60 80 100 Kilometres

SMC 15317

Figure 2–Index map showing location of Confederation Lake area in relation to subprovinces in northwestern Ontario.

sense. Formations have been given informal alphabetical designations rather than formal names inasmuch as (1) the stratigraphy is tentative in nature, (2) the extent of the formations is not well known outside this area, and (3) alphabetical designation provides the reader with a means of location within the stratigraphic section (Table 1). Formational nomenclature and type sections will be described in Thurston and Hodder (in press). Formations are shown on Figure 3 (Chart A, back pocket), and are readily relatable to the lithologic map in the back pocket. Cycle I (see Figure 5) has a maximum thickness of 4800 m west of the fold axis. It is made up of formation A (Figure 3, Chart A and map in back pocket), largely mafic flows, both pillowed and massive; overlain by formation B, a wedge of wacke-type sandstones with minor felsic tuffs and fine to medium pyroclastic rocks of intermediate composition; capped by formation D, about 100 m of marble and scattered lenses of massive pyrite and pyrrhotite 60 to 70 m thick. Formation C, largely felsic pyroclastic rocks, occurs as a small pod which interfingers with formation A at the southwest end of Narrow Lake on the west limb of the regional synclinorium, and again on the east limb above

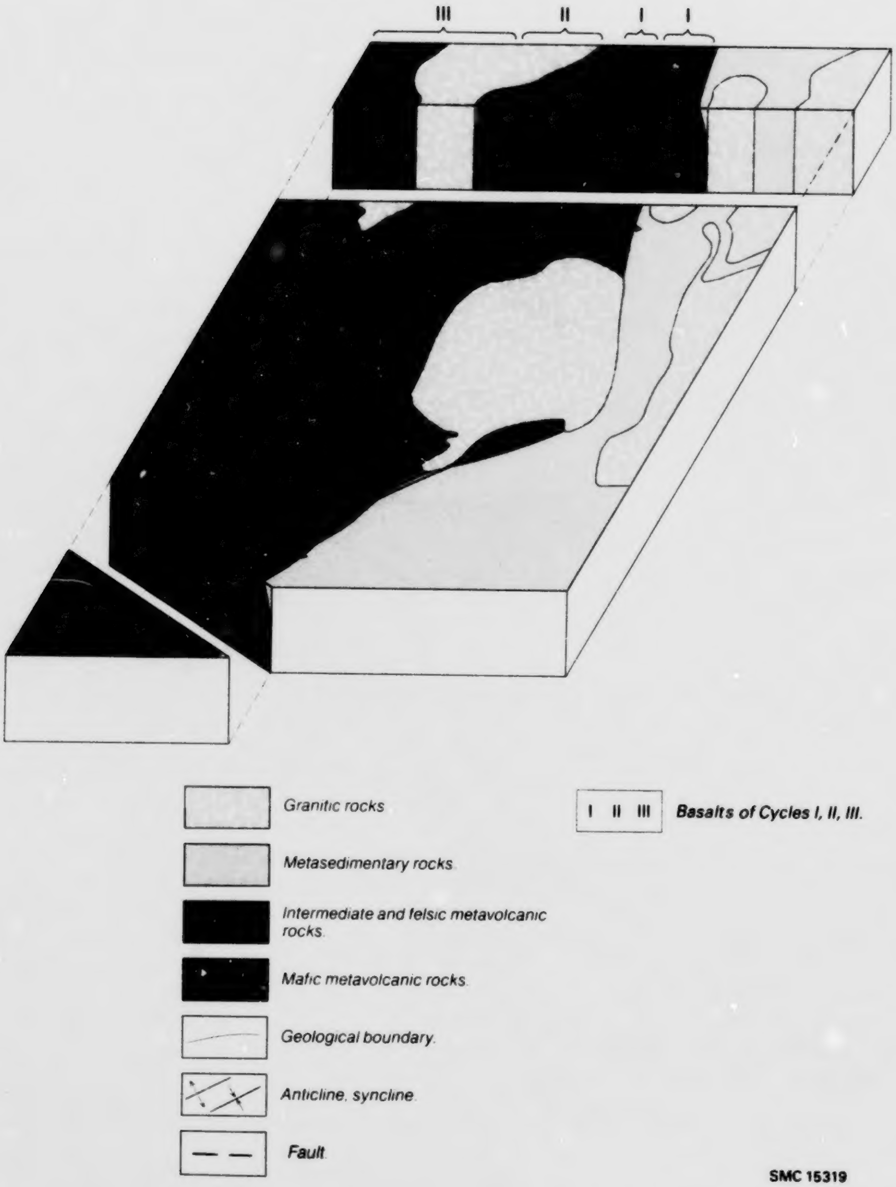

III
II
I
I
Granitic rocks.
Metasedimentary rocks.
Intermediate and felsic metavolcanic rocks.
Mafic metavolcanic rocks.
Geological boundary.
Anticline, syncline.
Fault.
I II III Basalts of Cycles I, II, III.
SMC 15319

Figure 4–Block diagram of Earngey, Birkett, Agnew, and Costello Townships showing structure of the eastern part of the Confederation Lake area. The central synclinorium is on the western edge of the diagram and the Leg Lake anticlinorium is on the eastern edge.

TABLE 1 TABLE OF STRATIGRAPHIC FORMATIONS FOR THE CONFEDERATION LAKE AREA.

FORMATION	CYCLE	PRINCIPAL ROCK TYPES	MINOR ROCK TYPES
M	III	Felsic lapilli-tuff, tuff-breccia	Felsic flows, tuff, mafic flows
L	III	Intermediate tuff and lapilli-tuff	Intermediate, flows, tuff-breccia
K	III	Mafic to intermediate pillowed flows	Hyaloclastic debris, massive variolitic flows, interflow metasediments
J	II	Marble	Chert, oxide facies iron formation
H	II	Felsic lapilli-tuff	Tuff, tuff-breccia, porphyritic flows
G	II	Intermediate lapilli-tuff and tuff	Argillite, chert, wacke, tuff-breccia, tuff, lapillistone
F	II	Mafic flows	Felsic tuff, mafic hyaloclastite
E	II	Mafic and intermediate flows	Intermediate and felsic tuff, cherty interflow units, oxide facies iron formation
D	I	Marble	Chert and sulphide facies iron formation
C	I	Felsic lapilli-tuff	Felsic tuff
B	I	Wacke, argillite, intermediate lapilli-tuff	Felsic tuff
A	I	Mafic flows, massive and amphibole phyric	Intermediate tuff and lapilli-tuff, feldspar phyric mafic flows

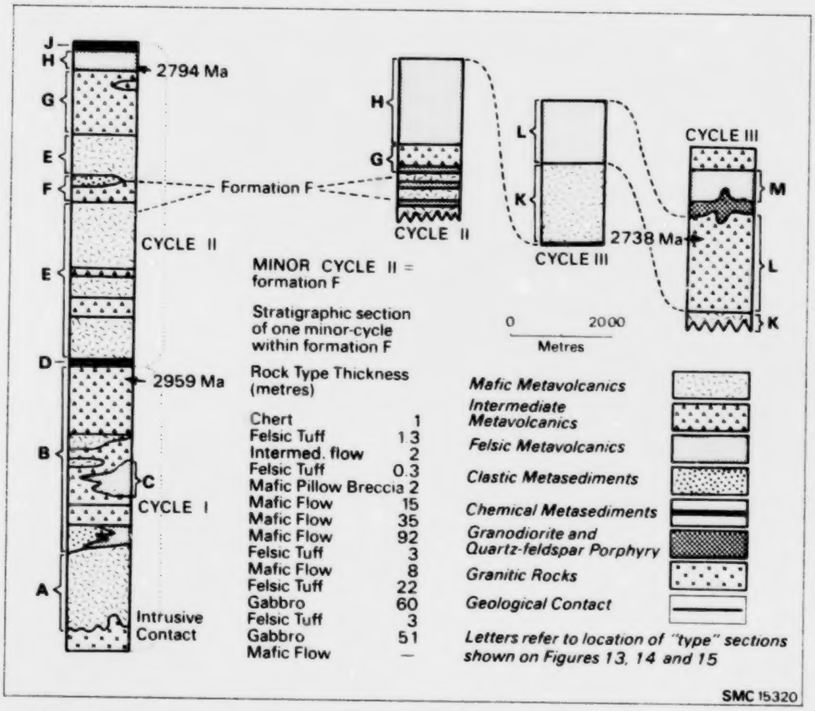

J
H
G
E
F
E
D
B
A
2794 Ma
Formation F
CYCLE II
2959 Ma
C
CYCLE I
Intrusive Contact
H
G
CYCLE II
MINOR CYCLE II = formation F
Stratigraphic section of one minor-cycle within formation F
Rock Type Thickness (metres)
Chert 1
Felsic Tuff 1.3
Intermed. flow 2
Felsic Tuff 0.3
Mafic Pillow Breccia 2
Mafic Flow 15
Mafic Flow 35
Mafic Flow 92
Felsic Tuff 3
Mafic Flow 8
Felsic Tuff 22
Gabbro 60
Felsic Tuff 3
Gabbro 51
Mafic Flow —
L
K
CYCLE III
2738 Ma
CYCLE III
M
L
K
0 2000
Metres
Mafic Metavolcanics
Intermediate Metavolcanics
Felsic Metavolcanics
Clastic Metasediments
Chemical Metasediments
Granodiorite and Quartz-feldspar Porphyry
Granitic Rocks
Geological Contact
Letters refer to location of "type" sections shown on Figures 13, 14 and 15
SMC 15320

Figure 5–Stratigraphic section of the Confederation Lake area with representative thickness. U-Pb radiometric ages are of rhyolites.

formation A. On the east limb formation C grades vertically and laterally into arkosic wacke and feldspathic lithwacke called the Slate Lake Series by Bateman (1940c).

A rhyolite from the upper part of Cycle I is 2959 Ma old according to a U/Pb age determination on zircons (Nunes and Thurston 1980).

Cycle II, exposed west of the synclinorial axis, is composed of pillowed and massive mafic flows of formation E and their coarse-grained intrusive equivalents, with interdigitations of pillowed flows of intermediate composition and chemical metasediments; formation G, pyroclastic rocks of intermediate composition both in place and their transported, reworked equivalents, capped by formation H, felsic pyroclastic rocks including 100 to 500 m of welded ash flow (Savory 1976; Thurston 1979).

Formation F, which is approximately correlative with the middle part of formation E on the west limb, is characterized by small-scale cyclical alternation of mafic flows and felsic tuff. Four such repetitions shown in detail on Map 2428 (Thurston, in press) occur on the east limb of the synclinorium.

The cycle is topped by formation J, a 100 m thickness of stromatolitic carbonate rock with minor cherty lenses. This cycle has a maximum thickness of 6500 m and an average thickness of 3640 m. East of the synclinorial axis, formations G and H are comprised of submarine pyroclastic flows and formation J is an oxide facies iron formation.

Two rhyolites from Cycle II are 2794 Ma old as defined by U/Pb age determinations on zircons (Nunes and Thurston 1980).

Cycle III is composed of formation K, a sequence of pillowed and massive and generally epidotized, mafic and intermediate flows including a prominent variolitic unit; succeeded upwards by formation L, submarine pyroclastic flows and tuff of intermediate composition; and formation M which consists of pyroclastic rocks of felsic composition. Most of formation M is within a fault-bounded block (Figure 3, Chart A, back pocket) containing a sequence of dominantly felsic pyroclastic rocks called the Mine Series by Sopuck (1977) and their coeval felsic intrusions including a quartz-feldspar porphyry stock likened to an endogenous dome by Pollock *et al.* (1972). Average thickness of Cycle III is 3950 m.

A rhyolite and the rhyolitic quartz-feldspar porphyry stock are 2738 Ma old according to a U/Pb age determination on zircons (Nunes and Thurston 1980).

The rocks of Cycle III are cut by sills and plugs of intermediate composition including biotite-sericite granodiorite and chloritic granodiorite. These intrusions which have a prominent metamorphic foliation are cut by unfoliated granite batholiths. The Perrigo Batholith, consisting of four phases ranging in composition from hornblende monzonite through hornblende-biotite granite, and the Allison Lake Batholith, which is largely pegmatitic muscovite granite are representative of these late granitic rocks (outside map area, see Thurston, in press).

The rocks of the Birch-Uchi Belt were involved in a complex series of deformational and metamorphic events which are summarized in Table 2 (Thurston and Breaks 1978, Table 2). The important events are as follows.

1. The first folding, D_1, which predates development of cleavage, produced isoclinal folds and nappes.

2. The first metamorphism, M_1, is marked by the formation of inclusion trains preserved in staurolite, biotite, andalusite, and almandine porphyroblasts.

3. The main regional metamorphic event, M_1A, produced the major foliation with a preferred shape orientation of chlorite, biotite, hornblende, muscovite, cordierite, almandine, and sillimanite.

4. D_2, is the main regional folding, with rotation of M_1 porphyroblasts and intrusion of the late granitic rocks (map, back pocket).

Several other relatively minor events listed in Table 2 culminated in the development of major strike-slip faulting including the Bear Lake Fault extending from Uchi Lake through Fly Lake westward to Bear Lake. This strike-slip structure shows a left-lateral horizontal displacement of Cycle III mafic rocks of some 1.5 km (see map, back pocket).

The volcanic rocks of the Confederation Lake area represent a relatively

TABLE 2 METAMORPHIC AND DEFORMATION EVENTS IN THE UCHI AND ENGLISH RIVER SUBPROVINCES (after McRitchie and Weber 1971).

		S_0	Original sedimentary and volcanic fabric.
D_1			Isoclinal folds in volcanic sequences and nappes in the Red Lake-Bee Lake areas.
	M_1	S_1	Development of planar fabric preserved as inclusion trains in staurolite, biotite, and almandine and andalusite.
	M_1A		Main regional metamorphic event. Development chlorite, biotite, hornblende, muscovite, cordierite, almandine, sillimanite. Migmatization of metasediments in English River Subprovince probably commenced.
D_2			Regional folding, rotation of M_1 porphyroblasts associated with emplacement of granitic intrusions in Uchi volcanic sequence.
	M_2	S_2	Matrix coarsening and development of main axial plane schistosity of biotite and muscovite parallel to D_2 folds. Further migmatization of metasediments in English River Subprovince; minor volumes of mobilizate controlled by axial surfaces of mesoscopic D_2 folds.
D_3			Large-scale S folds.
	M_3	S_3	Muscovite parallel to D_3 axial planes, pinitization of cordierite and andalusite.
D_4		S_4	Late stage development of mylonite on strike-slip faults.
	M_4		Retrograde muscovite and chlorite in shear zones of D_4.
D_5		S_5	Late transcurrent faulting, Bear Lake Fault.
	M_5		Minor recrystallization associated with D_5.

proximal facies as determined from the following observations.

1. the presence of siliceous domal intrusions emplaced to high levels in the crust
2. the presence of abundant coarse siliceous pyroclastic rocks
3. the thick mafic section in the map area relative to areas farther north and south (Breaks *et al.* 1975; Thurston 1977)
4. the presence of numerous intermediate synvolcanic dikes cutting the pyroclastic rocks of intermediate composition of Cycle II
5. the scarcity of metasediments.

South of Confederation Lake toward the English River Subprovince, as defined by L.D. Ayres *et al.* (1971), the proportion of metasediments increases; the thickness of the volcanic rock accumulation decreases (Breaks *et al.* 1974; Breaks *et al.* 1975), mafic sections contain higher proportions of pillow lava with fewer if any recognizable hyaloclastic sections; felsic and intermediate pyroclastic rocks are usually more thinly bedded and finer grained; the thickness and abundance of chemical sedimentary rock such as oxide facies iron formation becomes greater.

Breaks *et al.* (1974, 1975; Breaks and Bond 1976) note that the English River Subprovince has a northern metasedimentary domain (just south of the Confederation area) in contact to the south with a southern plutonic domain containing scattered fragments of rocks in the granulite facies of regional metamorphism with a minimum age of 3.3 Ga (Hinton and Long 1979). The boundary between the Uchi and English River Subprovinces was placed by Wilson (1971, p.44) and by Breaks *et al.* (1974) at the Sydney Lake Cataclastic Zone. Breaks *et al.* (1975) and Thurston (1977) interpret the metasediments of the English River Subprovince to be the stratigraphic equivalent of the upper part of the Cycle I metavolcanics of the Uchi-Confederation Lakes area and are probably also correlative with Cycles II and III. Thurston and Breaks (1978) state that there is an abrupt increase in metamorphic grade south of the Sydney Lake Cataclastic Zone with isograds paralleling the zone for some distance to the south. Thurston and Breaks (1978) discuss the probable movement on this fault.

Hence lithologies of the Uchi Subprovince and the English River Subprovince represent a continuum from respectively, proximal dominantly volcanic, to distal increasingly sedimentary, time-equivalent units 2.8 Ga old (Krogh and Davis 1971) deposited upon an older 3.3 Ga (Hinton and Long 1979) tonalitic basement of higher metamorphic rank. Although the Sydney Lake Cataclastic Zone may represent a very early structure, the available evidence indicates that it was active only during the deformational history of the area. Although it marks an abrupt change in metamorphic rank, it is not an abrupt lithological boundary.

Early Precambrian (Archean)

CYCLE I

Formation A

Basalt of formation A is grey to green on fresh surface and weathers in shades of brown and green. Flows are 15 to 60 m thick east of Leg Lake and have concordant contacts with interflow tuff of intermediate composition although locally there is brecciation and inclusion of blocks of tuff in the basalt. The basalt flows are massive, slightly pillowed, or well foliated. The massive flows have no apparent primary features over outcrops 35 by 30 m and only equivocal hyaloclastite and pyroclastic zones are observable in thin section at low magnification. Massive flows grade laterally and vertically into pillowed flows north of Leg Lake and on the west side of the regional synclinorium where the regional metamorphism is amphibolite facies grade and the massive flows appear gabbroic. Pillowed flows, for example south of Wagner Lake and at Philchub Lake in Costello Township (Thurston *et al.* 1975a), have pillows 0.6 by 0.2 m with selvages 2 to 4 cm thick. Interpillow material consists of quartz and calcite.

The basalt is equigranular to porphyritic with rounded hornblende phenocrysts 3 to 6 mm in diameter pseudomorphous after pyroxene. Metamorphic assemblages are listed in Table 3. The groundmass is fine-grained blastophitic to isogranular plagioclase and amphibole (Oppenheim 1964) (Photo 1a). There are amygdaloidal flows south of Philchub Lake in which amygdules are 1 to 2 mm in diameter, consist of quartz and calcite, and account for 1 to 2 percent of the rock. The mafic metavolcanics of formation A are distinguished from those of formations E, F, and K by the greater abundance of porphyritic flows with both feldspar and pyroxene phyric varieties represented. Formation A is overlain by formations B and C.

Leg Lake Sills

Cycle I mafic metavolcanics are cut by several sills and minor dikes of mafic and ultramafic rocks called the Leg Lake Sills (Thurston 1977). They are differentiated bodies exposed over a strike-length of 7.8 km from Drake Lake in the northeastern part of Earngey Township to beyond the south end of Leg Lake (Thurston *et al.* 1974). The Leg Lake Sills are concordant, but have clearly defined intrusive contacts with some marginal chilling and include small xenoliths of country rock. In addition, there are tabular inclusions within the sills of 3 to 4 m long laterally discontinuous of felsic and intermediate pyroclastic rocks east of Leg Lake and Manitoosh Lake. Features indicative of ultramafic flows such as polysutured texture (Pyke 1978a) are not present.

The sills are commonly separated from one another by thin septa of metavolcanics and metasediments.

The base of one sill extends the length of the east shore of Leg Lake and northeastward for 3 km beyond the north end of that lake. The sill is about 300 m thick and consists of a dunitic to peridotitic base 240 to 120 m thick succeeded upward by a gabbroic middle zone about 100 m thick, and a dioritic upper zone about 100 m thick. A second sill above the first has a 30 m thick tabular dunitic base, and a third consists of a 30 m thick tabular dunitic base beneath about 200 m of gabbro. Mafic flow and intermediate fine-bedded tuff, with a combined thickness of 120 m overlie this intrusion. Still a fourth sill, 300 m thick, is of a similar nature. Contacts between the ultramafic base of the sills and the surrounding supracrustal rocks were not observed.

Dioritic parts of the sills weather in various shades of green to dark grey and are black on the fresh surface. One variety, however, has a white weathered surface showing up to 30 percent subhedral green amphibole crystals, 1 to 2 mm in size, randomly scattered in a matrix of saussuritized plagioclase. Rel-

TABLE 3 METAMORPHIC MINERAL ASSEMBLAGES IN MAFIC METAVOLCANICS, EARNGEY-COSTELLO TOWNSHIPS.

Amphibolite Facies

Plagioclase An_{25-35}, hornblende, chlorite, carbonate
Hornblende, quartz, epidote, garnet, carbonate
Hornblende, plagioclase, biotite, chlorite, epidote, quartz, carbonate
Plagioclase, An_{25-35}, hornblende, tremolite, biotite

Greenschist Facies

Albite, tremolite, epidote, chlorite, biotite, carbonate
Albite, tremolite, quartz, epidote, biotite, chlorite, carbonate
Tremolite, albite, hornblende, epidote
Chlorite, albite, carbonate, epidote
Biotite, albite, quartz, carbonate, chlorite, epidote
Albite, chlorite, epidote, quartz, carbonate

ict subophitic to ophitic textures are present (Photo 1d) in areas of greenschist facies metamorphism but obliterated by recrystallization of tremolite-actinolite to hornblende near the Perrigo Batholith (see map, back pocket). Gabbroic parts of sills have similar textures, grain size, appearance, and mineralogy except for the near absence of quartz and a slightly higher colour index.

Dioritic and gabbroic parts of the sills have poorly preserved primary mineralogy. Sites of plagioclase laths, about 1 by 5 mm in size and An_0 to An_5 in composition are partly to completely occupied by tightly packed anhedral grains of epidote from 0.01 to 0.02 mm in diameter or plates of epidote from 0.2 to 0.5 mm long. Plagioclase has also been replaced by felted masses of acicular actinolite. Tremolite, which is colourless to light green, pleochroic, and in 2 by 3 mm grains; 0.02 by 0.1 mm needles of anthophyllite are the common ferromagnesian minerals. A few small areas of primary clinopyroxene are present as in specimen 73-12-723. Accessory minerals include epidote as very fine grained material after plagioclase and in much larger grains up to 0.8 mm long, sphene, iron-titanium oxides, and minor chlorite. The rocks typically exhibit a relict ophitic texture.

The ultramafic base of the Leg Lake Sills constitute 10 to 15 percent of the total thickness, and vary greatly in thickness. Weathered surfaces are black, through grey to white, depending on the abundance of talc and carbonate minerals. At the south end of Leg Lake, these ultramafic rocks are mottled with

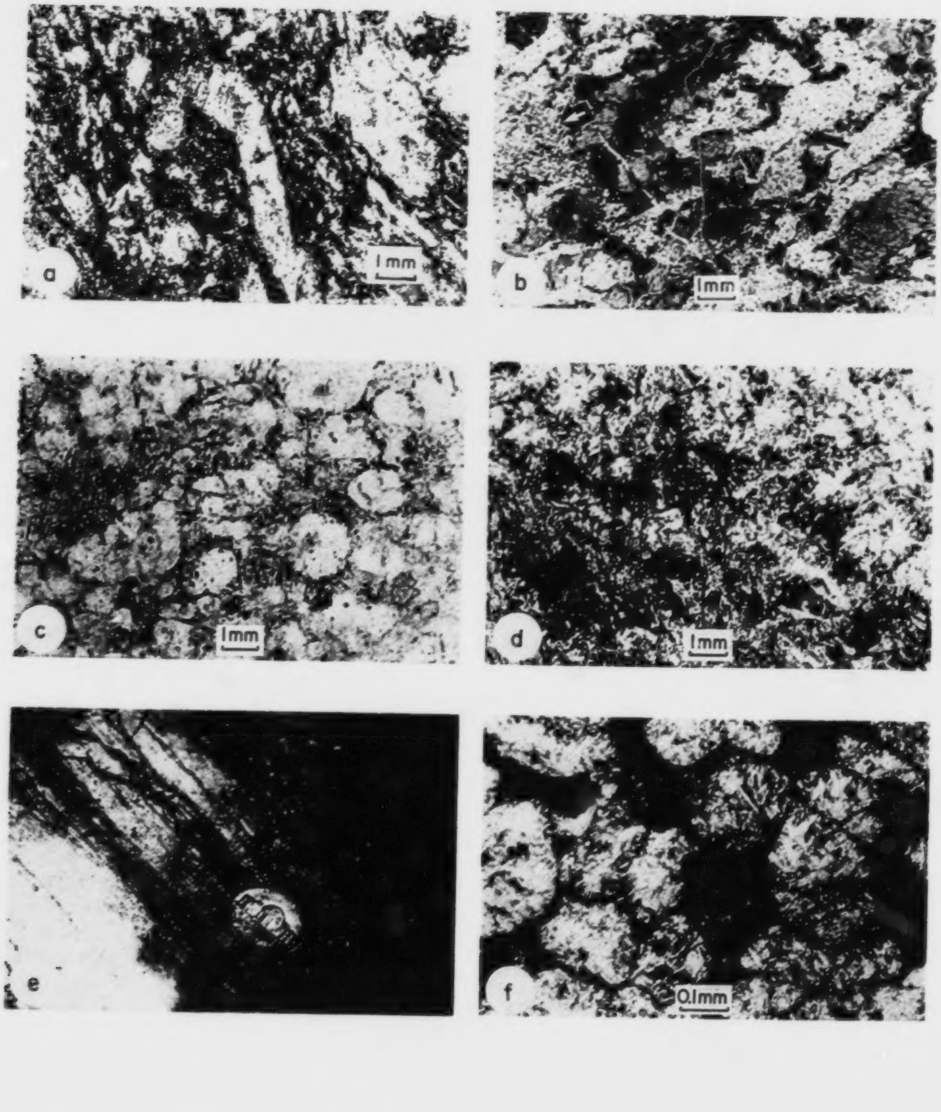

a
1mm
b
1mm
c
1mm
d
1mm
e
f
0.1mm

Photo 1a–Mafic flow of Cycle I. Coarse secondary plates of chlorite in a groundmass of fine-grained granular epidote and chlorite and laths of plagioclase. Specimen 73-12-2182, crossed polars.

Photo 1b–Intermediate lapilli-tuff, Cycle I, formation B. Coarse plates of hornblende and fine-grained albite, epidote, and biotite. Very fine grained aggregates of albite, epidote, hornblende, and biotite represent relict pumiceous clasts (arrow). Specimen 73-12-2251, crossed polars.

Photo 1c–Peridotite, Leg Lake Sills. Subhedral rounded grains of relict olivine, outlined by grains of magnetite, are now talc, tremolite, and carbonate. Specimen 73-12-194, plane light.

Photo 1d–Mafic flow, Cycle I, formation A. Laths of plagioclase now fine-grained albite, epidote, and hornblende after clinopyroxene. Specimen 73-12-723, crossed polars.

Photo 1e–Pumiceous felsic lapilli-tuff, Cycle I, formation C, on the southwest part of Narrow Lake. Dark streaks are sericite-rich devitrified glass between pumiceous lapilli. This locality was sampled for U-Pb age determination.

Photo 1f–Dunite, Leg Lake Sills. Relict olivine grains are now rounded aggregates of tremolite. Olivine grains are outlined by aggregates of talc with minor magnetite. Specimen 73-12-310, crossed polars.

TABLE 4 METAMORPHIC MINERAL ASSEMBLAGES IN MAFIC AND ULTRAMAFIC METAVOLCANICS OF THE LEG LAKE SILLS.

Gabbro and Diorite

- Plagioclase, epidote, chlorite, tremolite, actinolite, sphene, sericite, carbonate, quartz
- Plagioclase, epidote, hornblende, sphene, chlorite, biotite, iron oxides, quartz
- Plagioclase, epidote, tremolite, carbonate, talc
- Plagioclase, epidote, actinolite, quartz, sphene, talc anthophyllite

Peridotite and Dunite

- Talc, carbonate, iron oxides, chlorite
- Talc, carbonate, iddingsite, iron oxides, chlorite
- Serpentine, chlorite, carbonate, tremolite
- Serpentine, talc, carbonate, chlorite

blebs of dark green or black in a grey matrix. At the north end, both weathered and fresh surfaces are white to greenish white and soft. These rocks are serpentinized dunite and peridotite with recognizable cumulate textures and up to 5 to 10 percent primary minerals (Table 4). Spots on the fresh surface of the dunite are relict cumulate olivine grains up to 2 by 1 mm now replaced by serpentine, tremolite, and talc. As the intercumulus space becomes more abundant, the rocks grade into peridotite in which this space is filled with anthophyllite and iron-titanium oxides as in specimen 73-12-194 (Photo 1c), by chlorite as in 73-12-196, or by talc as in 73-12-310 (Photo 1f). The dunite is cut by 1 to 5 mm thick by 2 to 5 cm long veinlets of greasy green asbestiform amphibole. Anhedral grains of magnetite are scattered through the rock but do not exceed 5 percent. Serpentinization is quite complete at the north end of Leg Lake and to the northeast. Primary textures and mineralogy are best preserved to the south.

Peridotite in some outcrops contains 10 to 15 percent green pyroxene phenocrysts, 2 to 5 mm in diameter. In thin section, most pyroxene and all olivine are pseudomorphically replaced by serpentine, tremolite, talc, and carbonate with or without opaque iron-titanium oxides. These minerals form round clusters 0.8 to 0.6 mm in diameter and account for 75 percent of the rock (Photo 1c). Cumulate textures are present but indistinct. Relict pyroxene generally constitutes less than 5 percent of the rock, and contains very fine grained magnetite along cleavages. Most pyroxene has been pseudomorphed by magnetite and carbonate. Chlorite fills the intercumulus spaces. In some rocks, rounded serpentinized pseudomorphs after olivine are replaced at the edges or throughout by talc. Intercumulus chlorite is replaced by magnetite plus talc with large, 2 by 4 mm grains of dolomite replacing talc after pyroxene.

Dioritic and gabbroic dikes cut the sills and the basalt between sills. Contacts of the dikes are sharp with the sills and basalt. The dikes have a 1 to 4 cm thick chill zone adjacent to the country rock along the east shore of Manitoosh Lake and the east shore of Uchi Lake in the bay 1 km northeast of the Uchi Lake Lodge. Primary mineralogical layering defined by small variations in the amphibole and plagioclase content, is present only rarely in these dikes.

Formation B

Formation B occurs on both limbs of the regional synclinorium (map, back pocket, Figure 3, Chart A, back pocket). The formation is subdivided into member B_1, which consists dominantly of metasediments overlying formation A on the west limb and intermediate pyroclastic rocks and metasediments on the east limb, and the overlying member B_2, made up of intermediate pyroclastic rocks on the west limb and metasediments formerly the Slate Series (Bateman 1940c) on the east limb of the synclinorium.

Formation B contains relatively coarse fragments to the northwest on the west limb of the synclinorium in the Narrow Lake area, and becomes finer with appreciable amounts of admixed metasedimentary material toward the south. On the east limb of the synclinorium, formation B is generally thinner than on the west limb, and the formation generally fines upward from lapilli-tuff to tuff.

Member B_1 on the west limb consists of 0 to 1500 m of wacke-argillite with minor amounts of felsic tuff. This member is underlain by formation A, overlain by member B_2, and extends 6.5 km north from Bear Lake. Member B_1 has not been examined in detail but appears to be 10 to 15 cm thick beds of feldspathic lithwacke grading upward into siltstone with 2 cm thick argillite tops on many beds. Graded bedding and flame structures are the only primary features present.

On the east limb of the regional synclinorium, member B_1 is exposed on both sides of Leg Lake. It is on top of formation A and is overlain by member B_2. On the west side of the lake, the maximum thickness is 240 m; on the east side, a few scattered septa 30 by 150 m are included in the Leg Lake Sills. The south limit of member B_1 on the east side of the synclinorium is beyond the map area and the north limit, also beyond the map area, is the Swain Lake Fault. Mem-

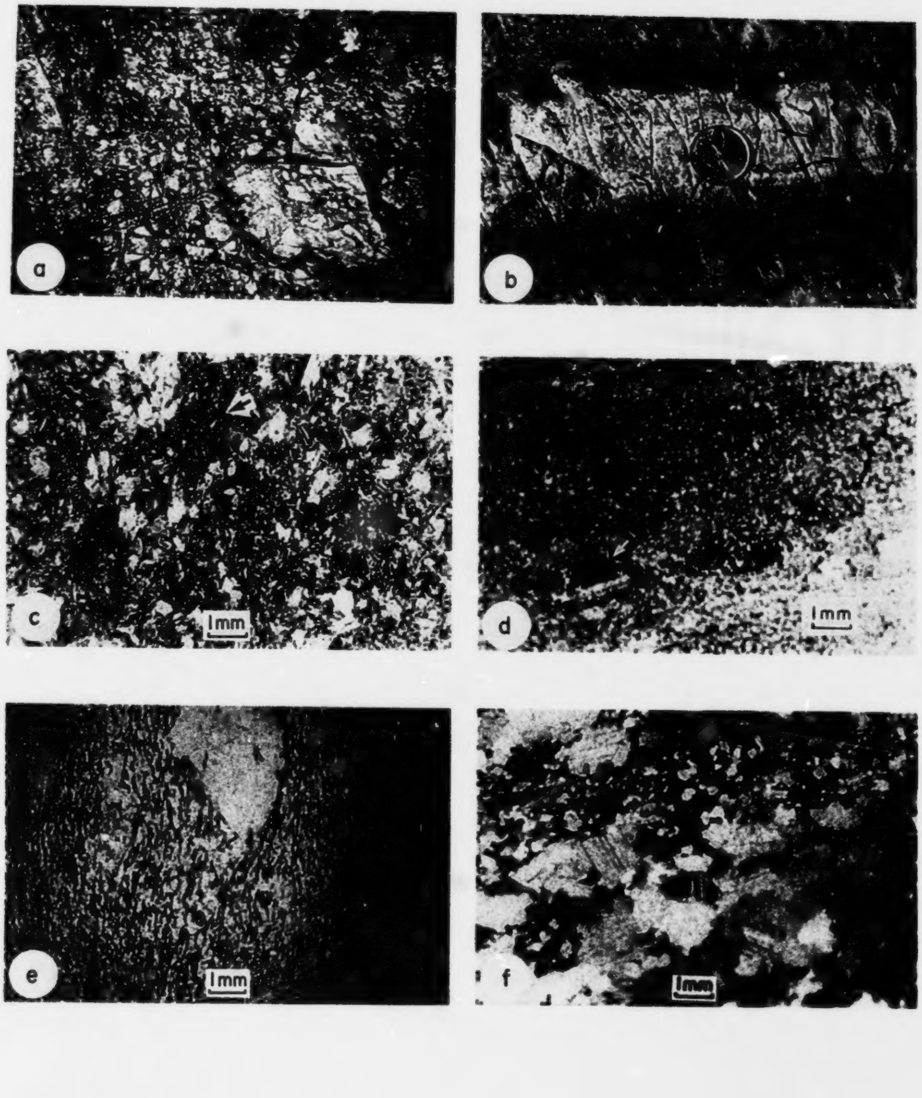

a
b
c
1mm
d
1mm
e
1mm
f
1mm

Photo 2a–Intermediate lapilli-tuff with rhyolitic pumice fragments in a matrix of intermediate tuff and fine-grained lapilli-tuff. The rounded nature of the fragments, heterogeneity of fragment types, and lack of primary structures such as bedding suggest the rock may be a debris flow. Cycle 1, formation B, shore of Spot Lake.

Photo 2b–Rhyolitic fine-grained tuff, Cycle I, formation B, with graded bedding above slightly coarser dacitic tuff. Note also, flame structures above the coin.

Photo 2c–Rhyolitic tuff fragments, Cycle I, formation B, in epiclastic rocks directly above intermediate pyroclastic rocks on the east limb of the Leg Lake anticlinorium. Relict pumice (arrow) consists of a fine-grained aggregate of albite, quartz, epidote, biotite, and tremolite-actinolite. The framework of the rock is secondary plates of tremolite-actinolite, relict twinned volcanic plagioclase grains, now fine-grained aggregates of albite and epidote. The matrix is acicular biotite and tremolite-actinolite. Specimen 73-12-84, crossed polars.

Photo 2d–Felsic crystal tuff, Cycle I, formation C. Plagioclase phenocrysts (arrow) occur in a bedded fine-grained aggregate of sericite, albite, epidote, and quartz. Specimen 75-1-259, crossed polars.

Photo 2e–Felsic crystal tuff, Cycle I, formation C, Narrow Lake. The matrix consists of a very fine grained aggregate of albite and quartz with interstitial biotite and sericite. Large phenocryst is quartz. Specimen 77-401, crossed polars.

Photo 2f–Marble, Cycle I, formation D, on central Narrow Lake, with carbonate and quartz-rich interbeds. Quartz is fine-grained aggregates; carbonate is in large plates. Specimen 77-402, crossed polars.

ber B_1 strikes northeast from the south end of Leg Lake for 14 km to west of One Island Lake in Costello Township (Thurston *et al.* 1975c) where it is cut off by the Perrigo Batholith. It reappears on the north side of the Perrigo Batholith, striking north for at least 13 km.

Rock types east of Leg Lake are fine to very fine grained tuff and lapilli-tuff which are delicately bedded on a scale of 0.5 to 1 cm. Graded bedding is common and recognizable in thin section by formerly glass-rich, now hornblende-rich, bottoms (see Photo 1b) overlain by finer grained feldspar-rich tops. More commonly tuff consists of 5 to 10 mm thick beds of fine-grained aggregates of saussuritic plagioclase, quartz, and tremolite-actinolite, with 1 mm acicular hornblende porphyroblasts making up 20 percent of the rock. Subhedral feldspar up to 1 mm in diameter occurs in this aphanitic melanocratic matrix.

Intermediate tuff occurs at the top of member B_1 west of Leg Lake. The tuff is bedded on a scale of 0.5 to 4 cm, with variation in the proportions of quartz and hornblende serving to define the bedding (Photos 2b, 2c). Ten percent of the rock is felsic lithic fragments consisting of 0.3 to 0.4 mm grains of quartz, feldspar, and hornblende. These fragments are set in quartz-biotite rich metasedimentary beds approximaly 0.5 m thick which contain 20 percent biotite (73-12-84). In the best preserved examples of similar lithologies, relict clinopyroxene with biotite rims is observed.

Lapilli-tuff of intermediate composition occurs on the northernmost peninsula on the east side of Uchi Lake. These rocks consist of 2 to 3 cm by 1 cm rhyolite clasts, which make up 10 percent of the rock, in a fine-grained matrix of oligoclase, quartz, hornblende, minor biotite, iron-titanium oxides, and epidote. The hornblende is poikiloblastic, up to 1 mm long, and has inclusions of quartz and feldspar.

Member B_2 on the west limb of the synclinorium, with a maximum thickness of 2700 m, marks the top part of Cycle I south of Narrow Lake. It is exposed for 15.5 km along strike, from the Bear Lake Fault on the south, north for 9.7 km to Narrow Lake where the strike becomes more westerly and eventually terminates against an intrusive contact at the west end of Narrow Lake (Figure 2). Member B_2 is underlain by member B_1, and overlain by formation D which includes 30 to 90 m of thin-bedded siliceous marble at central Narrow Lake which is correlative with quartzite and graphitic argillite at the south end of the lake. Locally formation B is overlain by metamorphosed felsic tuff of formation C at the west end of Narrow Lake.

Formation B_2 north of the south bay on Narrow Lake is thin- to medium-bedded intermediate lithic and crystal tuff, lapilli-tuff, and tuff-breccia. The latter consist of 20 percent subrounded fragments up to 0.3 m long, but averaging 0.1 m in long dimension in a fine tuffaceous matrix. On the scale of an outcrop 3 by 6 m, no bedding is recognizable (Photo 2a). The tephra are mainly essential holocrystalline lithic fragments of intermediate to felsic composition with no recognizable accidental fragments. In thin section, matrix and fragments are fine-grained aggregates of quartz and feldspar and rounded felsic to intermediate lithic fragments which together make up 20 percent of the rock. Inasmuch as this unit exhibits neither evidence of bedding nor size or density grading, and since it contains abundant matrix material it is considered to be a debris flow (cf. Parsons 1969).

A large area east and south of the Cycle I metavolcanics on the east limb of the regional synclinorium is underlain by arenite, wacke, mudstone, and clast-supported conglomerate of member B_2. These metasediments underlie substantial parts of the map area (Thurston *et al.* 1975b,c; Johns and Thurston 1975). In a regional context, the metasediments correlate with the upper part of Cycle I and all of Cycles II and III (Thurston 1977). Weathered surfaces are brown and crumbly, therefore, primary structures are rarely observed. Beds of arkosic wacke and arkose 15 to 45 cm thick, grade upward into feldspathic lithwacke beds of equal thickness capped by 1 to 15 cm thick beds of argillite. Graded bedding is obvious in thin section but not in outcrop.

The coarse-grained wackes contain grains which range from 0.5 to 2 mm in size, constitute 10 to 30 percent of the rock, and are set in a fine-grained matrix. This rock has a disrupted framework consisting of 10 percent clastic single quartz grains which exhibit undulose extinction and average 0.5 to 1 mm in diameter, and felsic metavolcanic fragments up to 2 by 3 mm. Where feldspar or lithic fragments dominate, the rock becomes a feldspathic lithwacke, lithic arkosic wacke, or arkosic wacke. The matrix is fine-grained quartz and feldspar overgrown by biotite, muscovite, and chlorite nearly the same size as framework clasts. Where the proportion of fine matrix is below 15 percent, the rock is properly termed an arenite.

Fine-grained wackes have a disrupted framework dominated by felsic metavolcanic lithic fragments which are angular to subangular, 1.8 to 2 mm in the long dimension and consist of fine-grained aggregates of quartz, albite, biotite, chlorite, and iron-titanium oxides. Lithic fragments make up at most 20 percent of the rock. Fifteen percent of the rock consists of detrital quartz grains which were possibly derived from a volcanic source as they are single unstrained grains, 1.8 to 2.0 mm in diameter and subangular to slightly rounded. The matrix which forms up to 30 percent of the rock is completely recrystallized, fine-grained, well rounded quartz and feldspar, and slightly coarser biotite, muscovite, and chlorite. Andalusite is present in accessory amounts. Poikiloblastic cordierite from 1.8 to 2.5 mm in size, forms up to 5 percent of the rocks (Table 5).

Arenites form the basal one third to one half of the graded, fining upward beds which range from arenite to wacke to mudstone. The arenites weather to a crumbly brown and consist in thin section of a framework of sericitized albitic plagioclase and quartz, with minor K-feldspar and rounded felsic lithic fragments averaging 2 to 3 mm in size. Accessory minerals include iron-titanium oxides, zircon, and apatite with relatively little sericite, epidote, and biotite.

Mudstone weathers brown to black and occurs in beds from 0.1 to 1 mm thick capping arenite-wacke units. The darker weathered surface relative to the other metasedimentary lithologies is a function of both fine-grain size and an appreciable iron-titanium oxide content. Thin beds show simple argillaceous partings at the top of fining upward arenite sequences. Thicker beds exhibit a blocky fracture and have black to dark brown fresh surface. The rock consists of variable proportions of 0.02 to 0.08 mm grains of quartz, albite, biotite, muscovite, epidote, and iron-titanium oxides with less than 20 percent rounded grains of quartz or lithic fragments.

This arenite-wacke-mudstone suite can be interpreted as a sequence of A to E turbidites (Walker 1976, p.26) which implies a relatively proximal facies. Graded wacke and arenite divisions represent rapid settling of grains from sus-

TABLE 5 METAMORPHIC MINERAL ASSEMBLAGES IN METASEDIMENTS, EARNGEY-COSTELLO TOWNSHIPS.

Greenschist Facies

Quartz, albite, biotite with muscovite, andalusite, epidote
Quartz, albite, biotite with epidote, muscovite, chlorite
Quartz, albite, biotite with epidote
Quartz, albite, biotite with muscovite, chlorite, stilpnomelane, epidote
Quartz, albite, biotite with muscovite, staurolite (relict)

Amphibolite Facies

Oligoclase-andesine, quartz, biotite with chlorite, cordierite
Oligoclase-andesine, quartz, biotite with muscovite, chlorite, garnet, cordierite, epidote
Oligoclase-andesine, quartz, biotite with cordierite, muscovite
Oligoclase-andesine, quartz, biotite with muscovite, cordierite
Oligoclase-andesine, quartz, biotite with muscovite, cordierite, garnet, sillimanite
Oligoclase-andesine, quartz, biotite, cordierite, muscovite, microcline
Oligoclase-andesine, quartz, biotite with muscovite, cordierite, andalusite, garnet

pension, and argillite represents fine material which gradually settled out after passage of the turbidity current.

Formation C

Formation C is a mappable unit mainly on the west limb of the regional synclinorium at the south end of Narrow Lake (see map, back pocket) where it is an isolated pod of tuffs 2400 m long by 300 m thick. It is overlain by and interfingers with member B_2 on the west limb of the synclinorium. On the west limb the formation is underlain by formation A, and on the east limb, where present as a thin unit, by member B_2. On the east limb formation C is overlain by formation E.

On the east side of the regional synclinorium, formation C consists of less than 30 m of felsic tuff on the shore of Stope Lake. East of Leg Lake a small area 30 by 90 m of finely bedded felsic tuff occurs as a xenolith in mafic intrusive rocks. The major rock types are felsic lithic and crystal lapilli-tuffs with bedding 2.5 to 3.5 cm thick. These consist of alternating pumiceous lapilli-rich and devitrified glass-rich beds, lapilli-tuff, and tuff-breccia (Photo 1e). The weathered surface is generally white to yellowish brown and the fresh surface is white. Specimen 75-1-259 is typical and consists of thin-bedded (0.5 cm) felsic lithic and crystal tuff (Photo 2e) containing 10 percent quartz in elliptical polycrystalline aggregates 1 by 0.5 mm, and 10 percent rounded felsic lithic fragments in a matrix of quartz, feldspar, and sericite 0.03 mm in diameter (Photo 2d). Since this unit is pumice-rich with a tuffaceous matrix without well developed bedding or grading, and since it shows some evidence of development of a eutaxitic foliation (Photo 2d), it is interpreted as an ash flow (cf. Parsons 1969).

Formation D

A 90 m thick siliceous marble unit on the north shore of the south part of Narrow Lake is the topmost formation of Cycle I and represents an hiatus in volcanism. Formation D consists of quartz-rich beds 5 to 10 mm thick intercalated with marble beds of similar thickness. Stratigraphically beneath and 90 m to the south across the lake, felsic and intermediate metavolcanics are carbonate-rich, suggesting that the entire 90 m width of the lake is underlain by the chemical metasediments.

The marble weathers to a light tan colour and the quartz-rich beds which weather high are white. The marble consists of 5 mm thick bands of fine (0.03 to 0.06 mm), rounded clastic quartz grains and minor carbonate in a matrix of 90 percent coarse (0.2 mm) anhedral carbonate and 10 percent zoisite (Photo 2f).

Along strike, about 1.6 km to the southeast, a 69 m thickness of chert and graphitic metasediments described by Pryslak (1971a) can be correlated with the marble. The chert consists of fine-grained recrystallized chert with beds a few metres thick of massive pyrrhotite, observable only in poorly exposed pits on the north shore of Narrow Lake.

Geochronology

Fifty kilograms of thin-bedded feldspar- and quartz-phyric felsic lapilli crystal tuff from formation C was collected for a U/Pb age determination on zircons by P. Nunes of the Jack Satterly Geochronology Laboratory of the Royal Ontario Museum and the author. A slightly discordant minimum age of 2959 Ma was obtained (Nunes and Thurston 1980) using

$$\lambda_{238} = 0.155125 \times 10^{-9} \text{year}^{-1} \lambda_{235} = 0.98485 \times 10^{-9} \text{ year}^{-1}$$

CYCLE II

Formation E

Formation E occurs on both limbs of the regional synclinorium (see map, back pocket). On the west limb, these rocks have a maximum thickness of 2700 m, extending over a distance of 22.1 km from the Bear Lake Fault in the south to the east end of Narrow Lake in the north where the strike changes to an eastward direction. Formation E is underlain by marble of formation D. It is overlain by mainly intermediate pyroclastic rocks of formation G.

Formation E consists of massive and pillowed coarse-grained mafic flows, coarse-grained sills, hyaloclastic units, and minor pillowed flows of intermediate composition. There are also intercalations of oxide and sulphide facies iron formation, wacke and mudstone, chert, and fine-grained, finely bedded felsic tuff.

On weathered surface, the mafic metavolcanics of formation E vary from dark to light green, with black and darker shades of green predominating in areas affected by amphibolite or hornblende-hornfels grade metamorphism. In areas of greenschist grade fresh surfaces are grey to green to black.

Typically, flows vary in thickness from 1 to 10 m, but in some places they form monotonous pillowed sequences up to 15 m thick which have no apparent base or top and which are bounded by coarse-grained sills. Within these sequences long (2 to 3 m), thin (0.3 m), tube-like masses with quench-textured edges are considered to be lava tubes. More conventional bun- and balloon-shaped pillows averaging 30 to 40 cm by 20 cm are the most abundant pillow type. Selvages are up to 2 cm thick and interpillow space is filled with spalled devitrified relict glass or recrystallized chert with or without pyrrhotite and pyrite. Pillowed flows generally contain 25 to 30 percent carbonate-filled amygdules. Varioles of the liquid immiscibility type (Gélinas *et al.* 1976) are found concentrated in the centre of lava tubes in a few localities. Chlorite-rich, devitrified glass pillow margins are succeeded inward by a spherule-rich outer zone and a microlite-rich inner zone (cf. Dimroth *et al.* 1978).

Formation E on the east limb is comprised of hyaloclastite units plus flows of three types: (1) porphyritic flows with relatively fine-grained felted groundmass containing 1 to 5 mm amphibole pseudomorphs after pyroxene and fine-grained epidote after plagioclase (Photo 3b), (2) thick flows (30 to 60 m) with massive centres and pillowed tops in which grain size in the massive parts varies from 1 to 2 mm (east of Lost Bay appearing in part as gabbro on Thurston *et al.* 1974), and (3) thin, fine-grained, commonly pillowed flows with grain size up to 1 mm.

Massive and coarse-grained flows and sills, 30 to 100 m thick, are particularly abundant east of Lost Bay of Confederation Lake and in the Narrow Lake area (map, back pocket). They form ophitic-textured bodies containing thin tabular xenoliths of the surrounding rock types. Some intrusive contacts suggest these coarse bodies are mostly sills.

The overall dimensions of individual flows and hyaloclastite units are difficult to establish because of extensive lateral variations. However, it appears that individual mafic hyaloclastites which consist of fragments of mafic pillows in a matrix of fine mafic pillow debris and once glassy fragments (Photo 3c), can be followed along strike for at least 300 m. Larger fragments have prominent selvages covering at least part of their exterior. In many fragments, both with and without selvages, quartz- or carbonate-filled amygdules, 5 to 10 mm in long dimension, make up 5 percent of the rock. The fragments of pillows average 0.3 by 0.2 m and make up about two thirds of the rock. The matrix consists of mafic hyaloclastite fragments with a few accidental fragments such as 6 to 8 cm long clasts of jaspilitic iron formation or felsic pyroclastic rock. Some of the fragments are rimmed with an indistinct zone of very fine grained (0.002 mm) almost isotropic banded leucoxene, possibly derived by alteration of palagonite (cf. Furnes 1972, p.392), (Photo 3d). The matrix around the fragments consists of oval to round globules 0.25 to 2 cm in long dimension with zoning from a very fine grained exterior to a slightly coarser interior. The fine-grained material within the globules is made up of 0.6 to 0.2 mm tremolite grains, in a matrix of epidote granules (0.02 by 0.02 mm), which outlines individual albite grains (0.12 by 0.02 mm). The tremolite accounts for 20 percent of the rock and the albite 60 percent. Areas of chlorite found after hyaloclastic fragments (as large as 0.2 mm square) make up the other 20 percent of the rock. The matrix surrounding the globules is chlorite, epidote, albite, and up to 10 percent calcite.

Chert and minor pyritic chert occupy the interpillow space. The zoned nature of the globules, the presence of selvages on some of the pillow fragments marking them as parts of pillows, the squared-off, rectangular or plate-like (cf. Macdonald 1972, p.104) shapes of fragments in the matrix, and the delicate zoning of some matrix fragments all point to a hyaloclastic origin for these rocks rather than, for example, their formation as flow breccia (cf. Parsons 1969).

Primary mineralogy is rarely preserved and there are only a few examples of heavily saussuritized primary feldspars, and rare armoured clinopyroxene grains in mafic hyaloclastite and coarse-grained gabbro. Relict quench plagioclase crystals with swallow-tail morphology, and acicular grains of tremolite-actinolite pseudomorphic after quench crystals of olivine and pyroxene occur (cf. Gélinas and Brooks 1974; Bryan 1972). In mafic metavolcanics of the greenschist facies there are flows with relict ophitic, subophitic, and intergranular textures consisting of pseudomorphs of the tremolite-actinolite series after pyroxene and olivine, saussuritized and sericitized plagioclase, sphene, opaque iron-titanium oxide, apatite, pyrite, leucoxene, and rare quartz and biotite. Chlorite occurs after ferromagnesian minerals and after plagioclase. Magnetite octahedra from 0.5 to 1.5 mm in diameter are common as accessories and generally concentrate at pillow margins in isogranular to ophitic-textured matrix. The flows grade laterally and vertically into broken pillow breccia (Carlisle 1963).

Pillowed flows of intermediate composition occur sporadically through formation E, but are generally distinguishable from their neighbouring mafic flows only on the basis of chemical analysis. The greatest thickness and abundance of intermediate flows and attendant sills within formation E occur on the east limb of the regional synclinorium, and in the Narrow Lake area on the west limb. On Narrow Lake the formation thins to the southeast. Coarse-grained sills tend to occur toward the base of formation E, and mafic hyaloclas-

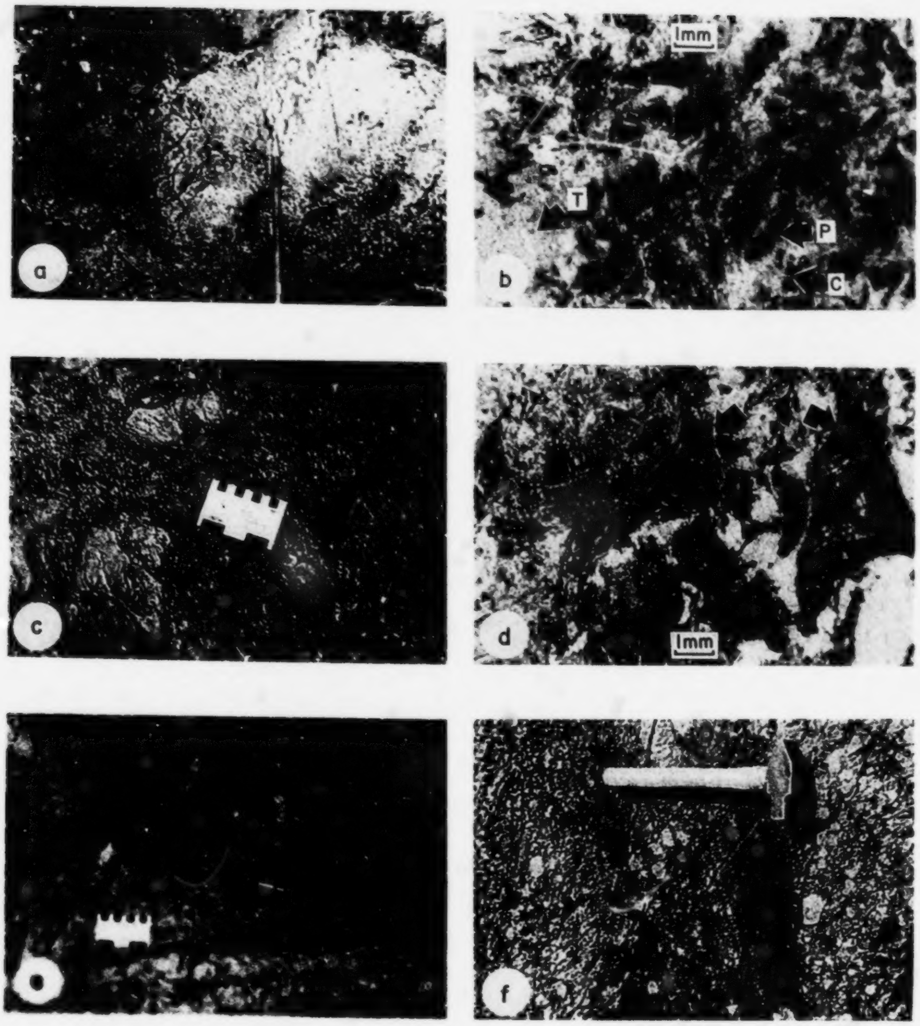

a
1mm
T
P
C
b
c
d
1mm
e
f

Photo 3a–Cycle II, formation E, central part of Narrow Lake. Variolitic pillowed mafic flow with Blake River type, liquid immiscibility varioles concentrated toward pillow centre at the sharp end of the pencil. The pillow rim is at the lower right.

Photo 3b–Amphibole phyric mafic flow, Cycle II, formation E. Light areas are aggregates of tremolite-actinolite with relict patches of clinopyroxene in light grey areas. Dark grey areas are aggregates of very fine grained epidote, pseudomorphic after plagioclase. Specimen 73-12-471, crossed polars.

Photo 3c–Mafic flow, Cycle II, formation F, on the road between Lost Bay and Uchi Lake. Isolated pillow breccia in a matrix of mafic hyaloclastite. Note chilled rim on the pillow below and to the left of the scale card. Short bars on scale card are equal to 1 cm.

Photo 3d–Mafic hyaloclastite, Cycle II, formation F. Dark areas are large relict glass fragments (arrows). Variation in darkness of these fragments represent alteration fronts within the fragments. Mineralogy is fine-grained sphene, chlorite, epidote, albite, and iron-titanium oxides. Specimen 73-12-2822, plane light.

Photo 3e–Subaqueous ignimbrite, Cycle II, formation G, Lost Bay. Pebbly intermediate tuff to lapilli-tuff forms the base of ignimbrite flow unit number II (Figure 7). Poorly developed crossbedding is parallel to the pencil.

Photo 3f–Subaqueous ignimbrite, Cycle II, formation G, Lost Bay. Intermediate lapilli-tuff with angular to subangular fragments of rhyolitic pumice in an ash matrix. Such bedding is sparse.

tite units toward the top. Intercalations of iron formation occur one third of the way up the formation on the west limb.

Flows of intermediate composition are abundant throughout Cycle II. Pillowed flows intercalated with mafic massive flows are found along the south shore of Narrow Lake (specimen 75-1-282), and more intermediate flows occur along the east shore of Narrow Lake (specimen 75-1-408a) and in the lower part of the Lost Bay section below the Hill-Sloan-Tivey quartz "vein' (HST) (Baker 1975). Variolitic mafic flows (Photo 3a) are found in the Narrow Lake area. Massive amygdaloidal and feldspar-phyric variants are also found in the Lost Bay section. In outcrop, intermediate flows are difficult to distinguish from mafic flows. Observed differences are thinner pillow selvages, up to 1 cm rather than 2 to 3 cm, and lighter green fresh surfaces for the former. There is also a spatial association between intermediate and felsic metavolcanics and a tendency for them to have lighter grey weathered surfaces than mafic flows. The abundance of intermediate flows is under-represented on the map and sections, but may be more correctly estimated from random geochemical sampling such as that done by Goodwin (1967). He estimated the proportion of andesite, which would almost entirely consist of flows, to be 8.3 percent of the "Lower Acid' section (Goodwin 1967), i.e. the upper part of Cycle II. Higher proportions of dacites and rhyodacites were tabulated by Goodwin for this section than in this report but an unknown amount of this would be pyroclastic in character rather than intermediate flow.

Formation F

Formation F, which is underlain by formation E and overlain by formations G and H, occurs only on the east limb of the synclinorium where it extends for 11 km with a thickness of 975 m in the area east of Lost Bay of Confederation Lake (see map, back pocket). It is correlative with oxide facies iron formation occurring part way through formation E on the west limb, and consists of the four cycles consisting of mafic flows and hyaloclastite units overlain by felsic tuffs (Thurston, in press, Maps 2427 and 2428). Each of these cycles is from 60 to 150 m thick.

Individual flows are rarely more than 6 m thick and more commonly 3 m or less in the HST area (Baker 1975). In the HST area, broken and isolated pillow breccia (Carlisle 1963) and hyaloclastic debris (Rittman 1962, p.82) are 3 to 10 m thick. In thinner flows, small pillows on the order of 10 cm by 6 to 8 cm are common, perhaps a reflection of low FeO and TiO_2 content (J.B. Fridleifson, National Energy Authority, Rey Reykjavik, Iceland, personal commumication, 1977). In thin section the mineralogy and textures of the mafic flows are similar to those observed in formation E.

The felsic rocks consist of fining upward beds 15 to 30 cm thick, of fine-grained tuff consisting mainly of relict glass shards which are composed of albitic plagioclase, epidote, and quartz, and more rare lithic fragments, grading from 1 to 2 mm shards at the base of beds to 0.1 mm shards at the top of beds. One of these small-scale cycles is capped by the HST quartz "vein' (Thomson 1939).

The HST quartz "vein' (Thurston, in press, Maps 2427 and 2428), is a generally conformable unit of quartz-rich material which extends for 2950 m and is enclosed within the metavolcanics. It has an average width of 57 cm ranging from 10 cm to 1 m. Baker (1975) notes that the vein is underlain by felsic airfall tuff which forms 15 to 25 cm thick fining upward beds in sequences about 3 m thick. It is everywhere overlain by mafic pillowed flow or massive to bedded hyaloclastite. The HST quartz "vein' is laminated parallel to strike. Quartz-rich laminae varying from 2 mm to 2 cm thick are separated by thinner (0.1 to 1.5 mm) more melanocratic laminae. Quartz-rich laminae are comprised of 75 to 90 percent sutured irregularly crystallized quartz grains averaging 0.5 mm in diameter. The remaining 10 to 25 percent is carbonate and untwinned albite. Muscovite occurs as small grains in more mafic laminae along with carbonates (both ankerite and calcite) and iron oxides. The calcite appears to be replacing quartz as irregularly shaped grains associated with fractures in quartz crystals. Ankerite is replacing quartz in selected areas. Tourmaline occurs as 0.1 mm isolated and clustered acicular crystals associated with sericite, but in some places single needles crosscut the laminae. Pyrite occurs as small subhedral to euhedral grains preferentially distributed in the quartz adjacent to the wall-rock. Numerous quartz veins cut underlying felsic tuff but not the HST "vein'. On the basis of sedimentary structures, and chert texture, this horizon is more correctly termed the Hill-Sloan-Tivey chert.

Formation G

Formation G is on both sides of the regional synclinorial axis. West of the axis it has a maximum thickness of 5400 m between Narrow Lake and Woman Lake in Goodall and Skinner Townships (Pryslak 1972a; A.P. Pryslak, Selco Exploration, Winnipeg, Manitoba, personal commumication, 1976). It is underlain by formation E on the west limb and by formation F on the east limb of the synclinorium and on the west side it is overlain by formation H, a minor accumulation of felsic metavolcanics near the top of Cycle II. On the east side of the synclinorium it is overlain by formation H. The Bear Lake Fault is the southern limit of formation G from which it extends northward for a distance of 9.8 km. There the strike deviates slightly westward, and the formation continues for a further 6.5 to 8 km to the Swain Lake Fault.

East of the synclinorial axis, formation G extends from Neepawa Bay of Uchi Lake, through Lost Bay of Confederation Lake, to the northern part of the Uchi Lake Fault. It is also centred upon Honeywell Lake. The southern limit is in English River terrain (Breaks *et al.* 1975), and to the north it is terminated by the Swain Lake Fault.

Formation G weathers to various shades of medium and light green to grey and white. There is some correspondence between the colour of the weathered surface and metamorphic rank. White surfaces predominate in areas of greenschist facies, and various shades of green are more common in higher grade areas. The abundant rock types in formation G are intermediate lapilli-tuff and lapillistone. These rocks consist of angular to slightly rounded lapilli, over 50 percent of which are pumiceous, 20 to 30 percent lithic fragments, and 10 percent accidental fragments made up of mafic volcanic rocks, iron formation, and less commonly, well bedded felsic to intermediate tuff and vein quartz. On the basis of chemical analysis of 2 to 3 kg bulk samples of medium- to fine-grained lapilli-tuff with similar petrography (cf. Thurston 1978), and inspection of colour index, the essential fragments are rhyodacite to andesite, with a predominance of the more siliceous types. The rocks have 10 to 20 percent fine tuffaceous matrix containing some relict glassy shards but mostly consisting of fine lithic grains.

On the shore of Lost Bay of Confederation Lake, formation G includes several sequences which grade upward from coarse, unbedded intermediate lapilli-tuff and pyroclastic breccia to fine-grained, parallel bedded pumiceous lapilli-tuff and tuff. Beds are 2 to 4 cm thick (Photo 3e). The subangular to rounded fragments consist of felsic pumice with subordinate felsic lithic fragments in a sparse ash matrix (Table 6). The ash matrix contains abundant poorly rounded, fractured quartz and feldspar phenocrysts. In places 0.1 to 0.3 m thick interbeds of tuff occur intercalated with the coarser pyroclastic rocks (Photos 3f, 4a-f), but in general the coarser rocks are chaotic, not bedded, and grade upward, into the fine-grained layers. The coarse to fine sequences are 30 to 300 m thick (cf. Figure 6).

Alternations between pumiceous lapilli-tuff and pumice-free tuff are conspicuous (Photo 4b). Pumice clasts decrease in abundance upward and bedding is defined by subtle variations in the relative abundance of subhedral 2 to 5 mm feldspar crystals and slightly rounded quartz crystals. Above the coarser pumiceous lapilli-tuff and tuff, tuff containing mostly pumiceous clasts fines upward, and becomes more regularly bedded. Pumiceous clasts are smaller and less abundant in the upper part of the units; crystalline debris, shards, and clastic nonvesicular lithic fragments are more plentiful; laminations are thinner (Photo 4c), on the order of 0.5 cm. Parallel laminations over a lateral extent of 5 to 10 m can be observed. Convolute bedding caused by soft-sediment deformation is present in one 0.3 m thick layer. Parallel laminated fine- to ultrafine-grained tuff caps the Lost Bay succession (Photo 4c). Five to ten metre thick sections with bedding on the order of 0.5 to 1 cm thick are common. No pumice is present among the relict shards and crystalline debris.

The fining upward sequences are in places disturbed by the occurrence of 3 to 6 m thick beds consisting of 1 to 10 cm rounded clasts of pumice which occur just below the fine-grained, finely laminated tuff at the top.

Exposure in the Lost Bay section is erratic, but at least seven fining upwards sequences have been identified in various stages of completeness (Figure 7). The lateral exposure is limited to the north, and to the south these sequences wedge out (Thurston *et al.* 1974).

In the Narrow Lake section, pyroclastic units, 3 to 6 m thick, consist of unbedded, ungraded felsic lapilli-tuff to pyroclastic breccia with 80 percent angular pumiceous clasts in a matrix of felsic ash and broken feldspar crystals. There is chaotic, unbedded, felsic pyroclastic breccia containing subangular to rounded felsic pumice fragments, rare felsic lithic fragments and a few accidental fragments in 10 to 20 percent matrix. This becomes less chaotic with distinct tuffaceous upper parts toward Narrow Lake. At 2 to 6 m intervals these coarse pyroclastic rocks are capped by 2 to 15 cm thick sequences of finely laminated felsic tuff beds 1 to 2 cm thick.

TABLE 6 | FIELD CHARACTERISTICS AND PETROGRAPHY OF SUBAQUEOUS IGNIMBRITES OF FORMATION G.

ROCK TYPES	FRAGMENTS				SORTING	MATRIX	STRUCTURAL FEATURES	FIELD RELATIONS
	TYPE AND ABUNDANCE	ORIGIN	SIZE	SHAPE				
Lapilli-tuff to tuff-breccia	60 to 90 percent blocks and lapilli. Listed in order of abundance. 1: Felsic pumice with a few quartz and feldspar phenocrysts, long tube pumice. 2: Felsic pumice with quartz and feldspar phenocrysts, round bubble pumice. 3: Felsic lithic fragments with quartz and feldspar phenocrysts in aphyric matrix. 4: Intermediate pumice with 1 mm rounded bubbles, < 2 percent chlorite phenocrysts. 5: Feldspar crystals in massive blebs. 6: Pyrite and pyrrhotite.	Essential: 1, 2, 3, 5 Accessory: 4, 5 Accidental: 6	1 and 2: average 2-4 cm maximum 15-20 cm 3: average 2-5 cm 4: average 5 mm to 1 cm 5: < 1 cm 6: average 5-8 mm	1 and 2: subangular to rounded 3: subangular 4: flattened, wispy 5: euhedral to subhedral, commonly broken with slightly rounded corners 6: rounded	Generally unsorted although a few interbeds of ash are present	10 to 40 percent, consisting of fine relict shard-like shapes now chlorite, epidote, and albite pseudomorphs with about 25 percent broken quartz and feldspar phenocrysts.	1: Laterally extensive over 15 km minimum. 2: Concordant with respect to underlying units. 3: Massive unbedded, with a few tuff interbeds. 4: Decreases in thickness away from source. Average 30-60 m at Narrow Lake, and north part of Lost Bay, thinner to south, commonly only 10 m. 5: Fine-grained crossbedded tuff forms 0.6 m thick base of one unit.	Basal one third of each fining upward unit
Lapilli-tuff and tuff	30 to 60 percent lapilli and rare blocks, listed in order of abundance. 1: Felsic pumice with a few quartz and feldspar phenocrysts, long tube pumice. 2: As above, rounded pumice. 3: Felsic lithic fragments as in 3 above. 4: Feldspar crystals.	Essential: 1, 2, 3, 4	1 and 2: 2 to 5 cm 3: generally < 1 cm 4: 1-5 cm	1, 2, and 3 subangular 4: broken with slightly rounded corners	Generally alternating 1-5 cm thick pumice-rich and pumice-poor beds with the latter increasing upward in section.	40 to 75 percent consisting of relict shards and broken phenocrysts of quartz and feldspar	1: Laterally extensive. 2: Medium-bedded, fines upward with more tuff intercalations upward. 3: Rare development of reverse grading. Concentration upwards of pumiceous clasts.	Lies above lapilli-tuff to tuff-breccia.
Tuff	Rare felsic pumice with quartz phenocrysts.	Essential	1-2 cm	Rounded	Well sorted with pumice decreasing from 5 percent to nil over a vertical distance of 2 m.	Fine-grained chloritic tuff with 80 percent relict glass shards, 20 percent subhedral plagioclase phenocrysts.	1: Laterally extensive. 2: Medium- to thin-bedded. 3: Convolute bedding commonly developed as well as flame structures.	Lies above lapilli-tuff to tuff.
Fine tuff	A few plagioclase phenocrysts.	Essential	1-2 mm	Subhedral	Well sorted with graded bedding over 1 cm thickness with grains ranging from 1 mm to 0.2 mm. Based on size of primary feldspar grains.	Chloritic mesostasis due to devitrification.	1: Finely bedded.	Overlies all the above units. Finely bedded where directly overlying lapilli-tuff to tuff-breccia.

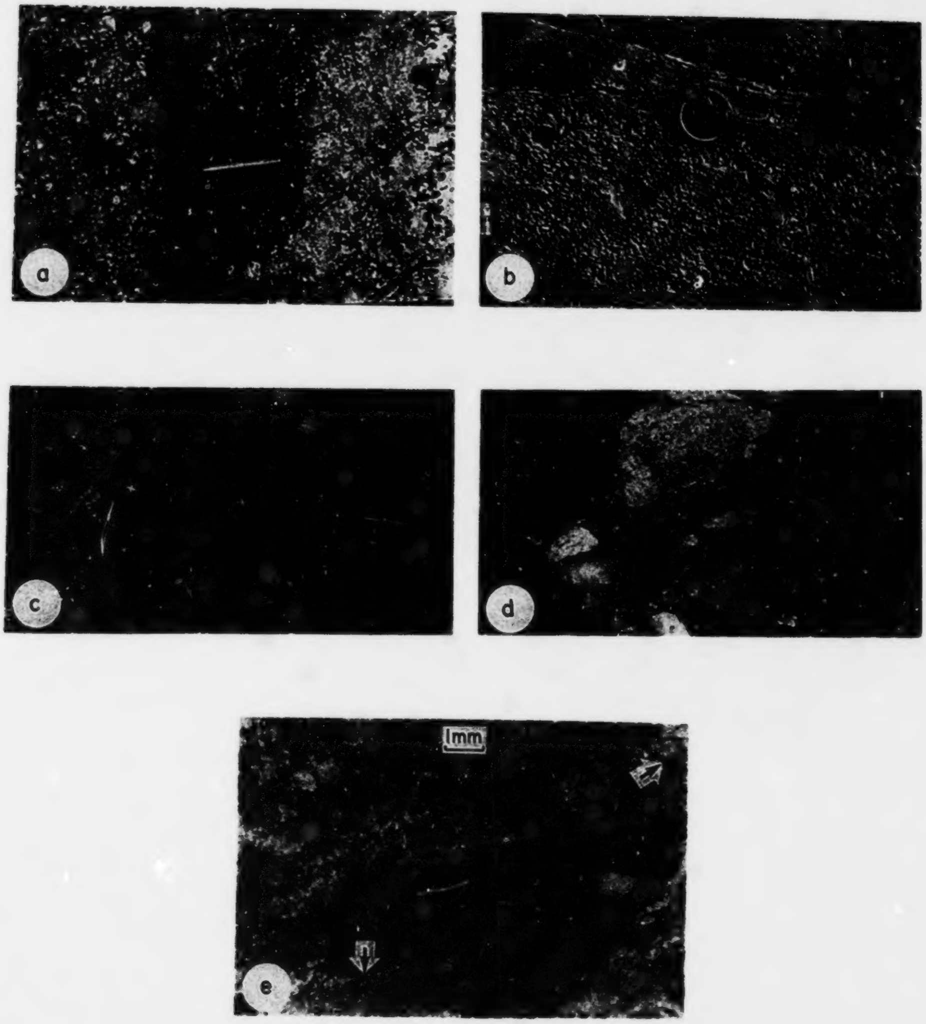

a
b
c
d
1mm
n
e

Photo 4a–Subaqueous ignimbrite, Cycle II, formation G, Lost Bay. Intermediate lapilli-tuff with interbed of tuff. This photo is of rock a few metres up section from that in Photo 3f.

Photo 4b–Subaqueous ignimbrite, Cycle II, formation G, west limb of fold on northern Narrow Lake. Sandy pumice tuff of Yamada (1973) is near the coin. Slightly coarser material is below the coin with subangular pumice fragments of low relief. This material is equivalent to that on the east limb lying above the material in Photo 3a.

Photo 4c–Subaqueous ignimbrite, Cycle II, formation G, Lost Bay. The uppermost part to the right of the knife is massive to finely laminated tuff. Underlying material to the left of the knife is slightly coarser.

Photo 4d–Subaqueous ignimbrite, Cycle II, formation G, Lost Bay. Sawn slab of pumiceous clast toward the base of unit I (Figure 7). Note vesiculated nature of clasts. Largest clast is 2 cm from left to right. Matrix includes many broken plagioclase crystals.

Photo 4e–Subaqueous ignimbrite, Cycle II, formation H, Lost Bay. Pumice-rich upper part of unit VI (Figure 7), consisting almost entirely of pumiceous clasts in an ash matrix. Note the fingerprint-like devitrification texture of pumice clasts (arrows lower left and upper right).

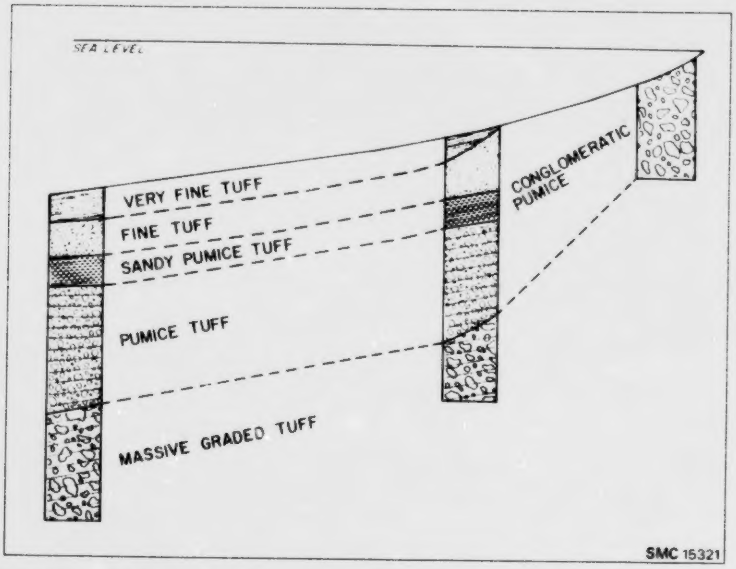


Figure 6–Facies model (after Yamada 1973) for subaqueous ash flows. Close to the eruptive site (right) chaotic pumiceous conglomerate occurs. Outward from this, bedding is better developed and a sequence of massive graded tuff with abundant blocks of pumice to very fine grained thinly laminated tuff occurs.

Primary mineralogy is generally not preserved. Primary zoned clinopyroxene phenocrysts occur in the lithic fragments of one lapilli-tuff (73-12-14 and 73-12-487). Unaltered plagioclase crystals occur in a few samples of intermediate crystal and lithic lapilli-tuff (73-12-489 and 73-12-2141). Mineral assemblages consist of plagioclase (mainly albitic), epidote, quartz, biotite, sericite, chlorite, and tremolite-actinolite with accessory magnetite, sphene, zircon, carbonate, and hornblende. Relict pumice features uncollapsed slightly elliptical vesicles which form 40 percent of the fragment. Vesicles are generally filled with quartz and carbonate, with or without chlorite. The rock is a fine-grained felted mass of chlorite, tremolite-actinolite, epidote, albite, quartz, and white mica with relict quartz and plagioclase phenocrysts.

Pumiceous fragments are usually subangular, irregular in shape, and composed of fine-grained albite with epidote inclusions, quartz, sericite, tremolite-actinolite, sphene, opaque iron-titanium oxides, and porphyroblasts of epidote. The pumiceous nature of the clasts is recognizable in elongate areas of quartz or quartz and feldspar surrounded by chlorite or epidote (Photos 4d, 4e). These

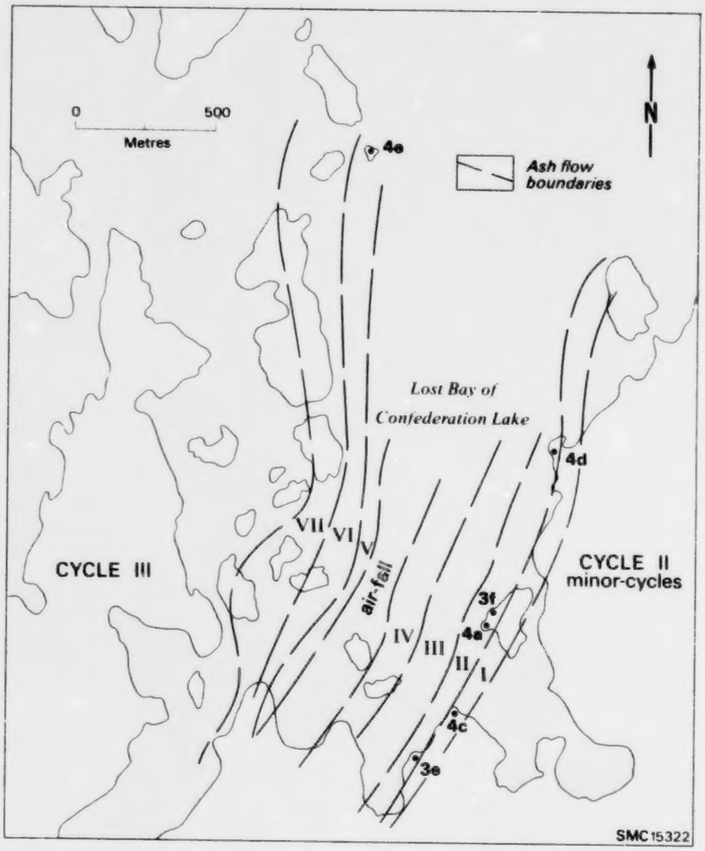

0
500
Metres
4e
Ash flow boundaries
N
Lost Bay of Confederation Lake
4d
VII
VI
V
air-fall
CYCLE III
CYCLE II minor-cycles
3f
4a
IV
III
II
I
4c
3e
SMC 15322

Figure 7–Subaqueous ignimbrites of the Lost Bay area. To the west of the minor-cycles of major Cycle II there are seven (roman numerals) subaqueous ignimbrites, with minor air-fall material above ash flow IV. The arabic numerals and letters refer to photographs. Since no good exposures of one complete ignimbrite are available, composite documentation of textures is presented by using exposures from several of the essentially similar rocks.

elongate quartz areas, with ragged wispy terminations on fragments, and very irregular outlines represent relict long-tube pumice and even rounded bubble type pumice (Photo 4e) (specimens 73-12-773, 1010) (cf. Fiske 1969).

Relict angular glassy fragments (Photo 4e, 73-12-1010) are typified by extremely fine-grained (less than 0.02 mm), closely packed aggregates of epidote and albite. Lithic fragments (Table 6) consist of secondary minerals similar to those in the pumice fragments. The ash-sized fraction consists of relict glassy rock fragments, now fine-grained recrystallized quartz and feldspar, relict glass shards, now fine-grained aggregates of biotite, epidote and carbonate, and broken subhedral quartz and plagioclase crystals.

TABLE 7 | CHARACTERIZATION OF SUBAQUEOUS VERSUS SUBAERIAL IGNIMBRITES.

SUBAQUEOUS	SUBAERIAL
Bedding: well-bedded relative to subaerial deposits with chaotic unbedded material proximal to vent, and well-bedded in the distal environment. (Yamada 1973)	Bedding: Ranges from massive, unbedded in the proximal environment to poorly bedded in the more distal. (Lajoie 1979)
Grading: Fining upward of fragments and matrix with some reverse size grading resulting in pumice-rich uppermost beds. (Yamada 1973; Fiske and Matsuda 1964)	Grading: Normal density grading, reverse size grading very common. (Sparks *et al.* 1973)
Fragment size: Fragment and matrix grain size generally less than in the subaerial environment. (Sheridan 1971; Walker 1971)	Fragment size: Fragment and matrix grain size is generally greater than in subaqueous environment. (Sheridan 1971; Walker 1971)
Sorting: Sorting is greater in this environment, particularly in the distal facies. (Yamada 1973; Fiske and Matsuda 1964)	Sorting: Less well developed. (Sparks *et al.* 1973)
Welding: Welding is not well developed, although it has been observed in the subaqueous environment. (Frances and Howells 1973)	Welding: Welding is commonly observed in subaerial ash flows. (Ross and Smith 1961; Sparks *et al.* 1973)
Recrystallization: Vapor phase recrystallization of pumice and ash matrix is not generally observed. (Frances and Howells 1973)	Recrystallization: Vapor phase crystallization of fragments and matrix, fumarolic alteration, and granophyric crystallization are observed in this environment in conjunction with the degree of welding. (Smith 1960)
Fragment type: Accessory fragments constitute up to 10 percent of the unit.	Fragment type: Accessory fragments are rare.

TABLE 8 | METAMORPHIC MINERAL ASSEMBLAGES IN FELSIC METAVOLCANICS, EARNGEY-COSTELLO TOWNSHIPS.

Amphibolite Facies

- Plagioclase, quartz, microcline, actinolite

Greenschist Facies

- Albite and quartz with microcline, biotite, epidote, carbonate
- Albite and quartz with microcline, muscovite, biotite, chlorite, epidote, carbonate
- Albite and quartz with microcline, biotite, chlorite, epidote, carbonate
- Albite and quartz with microcline, biotite, tremolite, epidote, chlorite
- Albite and quartz with microcline, chlorite, muscovite, epidote
- Albite and quartz with microcline, muscovite, chlorite, stilpnomelane, epidote, carbonate
- Albite and quartz with microcline, tremolite, chlorite, epidote
- Albite and quartz with microcline, muscovite, biotite, epidote, carbonate

GENETIC IMPLICATIONS

The presence of abundant pumice, reverse size grading, normal density grading, and lack of well developed bedding suggests that these deposits are the product of pyroclastic flow eruptions (cf. Sparks *et al.* 1973) and that they are submarine pyroclastic flows (cf. Lajoie 1979), (Table 7). Similar deposits have been described by E. Yamada (1973) who developed a facies model for subaqueous ignimbrites (see Figure 6). Utilizing this facies model, the coarse units at Mosier Lake represent a proximal facies, those at Narrow Lake a slightly more distal environment, and the Lost Bay sequence a relatively distal facies.

Formation H

Cycle II felsic metavolcanics of formation H are disposed on both sides of the regional synclinorium intercalated with and overlying the pyroclastic rocks of intermediate composition of formation G. Maximum thickness of formation H is 400 m in Dent Township (Pryslak 1970a); on the west side of the synclinorium, and in Goodall Township (Pryslak 1972a) to the north, the formation has an aggregate thickness of 540 m. Lateral extent of the felsic rocks in formation H is much the same as the mafic rocks of formation E but the felsic sequence is not continuous.

The felsic metavolcanics of formation H are overlain by formation J, which consists of chemical sediment. Formation H weathers white to grey with some examples being buff or light apple green in colour. The fresh surface is commonly vitreous in lustre and usually has a conchoidal fracture. Primary mineralogy is not preserved (Table 8).

Rock types on the west side of the synclinorium are tuff, lapilli-tuff, and minor tuff-breccia. In the area between Narrow Lake and Woman Lake in Goodall Township thin-bedded (0.5 to 3 cm) tuff forms a sequence up to 60 m thick. These tuffs consist of fine (0.1 by 0.15 mm), relict shards now made up of quartz, albite, chlorite, and sericite, and coarser subangular lapilli (3 to 10 mm) made up of epidote, chlorite, and opaque iron-titanium oxide which constitute 10 percent of the rock. Some of the thin-bedded tuff consists solely of relict shards and fine (less than 3 mm) lithic fragments fining upward to very fine quartz and albite (after shards) with no lithic fragments at the top, in delicate bands 5 to 10 mm thick. Lithic fragments in the lapilli-tuff are felsic, subangular to well rounded, and exhibit no grain size or colour changes toward their margins (Photo 5a). The matrix of the lapilli-tuff is felsic to intermediate lapilli-tuff with 10 to 20 percent angular to wispy relict pumice fragments now consisting of epidote, chlorite, albitic plagioclase, and quartz. The coarser rocks are in layers 2 to 5 m thick succeeded upward by a few centimetres of finely laminated tuff (Photo 5a). These are interpreted as proximal ignimbrites on the basis of the pumiceous nature of the coarse clasts, lack of bedding in the coarse rocks, and the association with thin-bedded tuff (cf. Fisher 1979).

At the top of formation H, a white weathering felsic tuff to lapilli-tuff with semi-vitreous lustre occurs at Woman Lake Narrows. This was studied first by Savory (1976) and then in more detail by Thurston (1979). The unit, which is called the Woman Lake Tuff (Thurston 1979), has a maximum thickness of 300 m, and extends along strike for 12 km. It is tuff, lapilli-tuff, and minor tuff breccia. Clasts are felsic pumiceous lapilli and bombs and fiamme. There are no accidental clasts. Essential mafic pumice (Photo 5e) is confined to a 2 m thickness high in the unit. The lapilli and bombs are uncollapsed vesicular relict glass with quartz and feldspar phenocrysts (Photo 6a), now fine-grained recrystallized quartz and feldspar and pumice. Felsic lithic fragments are largely relict non-vesicular glass containing feldspar phenocrysts, now fine-grained quartz and feldspar with accessory epidote and sericite. The fiamme are almost entirely quartz. The matrix consists of relict glass shards devitrified to aggregates of quartz, feldspar, epidote, and sericite.

The Woman Lake Tuff can be subdivided into a base and top, with the base containing larger, slightly more mafic, more vesicular pumice (Photos 5c, 5d), than the top which has more feldspar phenocrysts (Tables 9 and 10, Figures 8 and 9). The base and the top are separated by 15 cm of unbedded tuff. Both base and top include massive unbedded, ungraded, lapilli-tuff to tuff-breccia zones in which pumice increases in abundance and size upward (Table 10), followed by thin tuffaceous upper parts.

The matrix in the lowermost 10 to 30 m of the base and the uppermost 30 to 60 m of the top is made up of flattened relict glass shards, now equigranular fine-grained quartz, and feldspar with minor epidote and sericite. At one locality, both matrix and clasts consist of a uniform relict glass with a black weathered and fresh surface. This occurs 2 to 3 m above the base of the tuff, and there are no identifiable clasts or individual grains in the matrix over a stratigraphic interval of 3 to 6 m.

In the middle part of the Woman Lake Tuff, i.e. the upper part of the base and the lower part of the top, relict shards cannot be recognized; instead the matrix consists of oriented axiolites of fine quartz and feldspar with phenocrysts produced by vapor phase recrystallization of granophyric intergrowths of quartz and albite. Fine quartz-filled fractures trend perpendicular to bedding in this stratigraphic interval. Megascopically, the matrix is foliated in the central part of the Woman Lake Tuff with the foliation passing around pumiceous fragments more conspicuously than around lithic fragments (Photo 5b).

The length to width ratio of pumice clasts versus stratigraphic position measured after the method of D.W. Peterson (1961) (Figure 10), is greatest in the middle of the Woman Lake Tuff where flattening of clasts is extreme. There the clasts are mostly polycrystalline aggregates of quartz with relatively high epidote contents, and vesicles are generally absent. The upper 30 m and lower 30 to 60 m of tuff contain pumice clasts in which clasts and vesicles in clasts are only slightly flattened; they consist of relict glass now fine-grained quartz, feldspar, sericite, epidote, and minor carbonate, with a few feldspar phenocrysts.

Spherulitic intergrowths of feldspar are uncommon within lithic fragments in the middle part of the Woman Lake Tuff. In the upper part, branching fractures up to 6 cm wide by 0.5 m long trend generally perpendicular to strike. The fractures are filled with angular fragments of country rock and a chloritic relict glass mesostasis.

The lack of bedding, presence of abundant pumice, reverse size grading, normal density grading (Table 9), lack of accidental clasts, and the tuffaceous nature of the upper parts suggest that the base and top of the Woman Lake Tuff are both ignimbrite flows, each representing one eruptive event (Sparks *et al.* 1973). Within the base of the Woman Lake Tuff, layer 1 of Sparks *et al.* (1973) (Figure 8) is the thin-bedded tuff (Figure 9, Table 9). In the top of the Woman Lake Tuff, layers 2a, and 2b (Figure 8) are the main component. The uppermost 12 m represents layer 3 of Sparks *et al.* (Photos 5f, 6a).

The above textural changes in the matrix, and textural and mineralogical changes in the pumiceous clasts, coupled with the consistent stratigraphic control, the ash flow origin of the unit, the lack of high degree of strain of the nearby mafic flows, and analogy with younger rocks (Anderson 1969; Leonard 1979; Geijer 1913; Ross and Smith 1961; Snyder 1962) suggest that the Woman Lake Tuff can be subdivided into a central highly welded zone, enclosed above and below by partly welded zones and an unwelded base and top (Table 11). The boundary between the lower partly welded zone and the central welded zone occurs toward the top of the basal eruptive unit. Therefore the Woman Lake Tuff is a single compound cooling unit (Smith 1960) of two flows from two eruptive events.

By analogy with younger welded units (Smith 1960; Ross and Smith 1961),

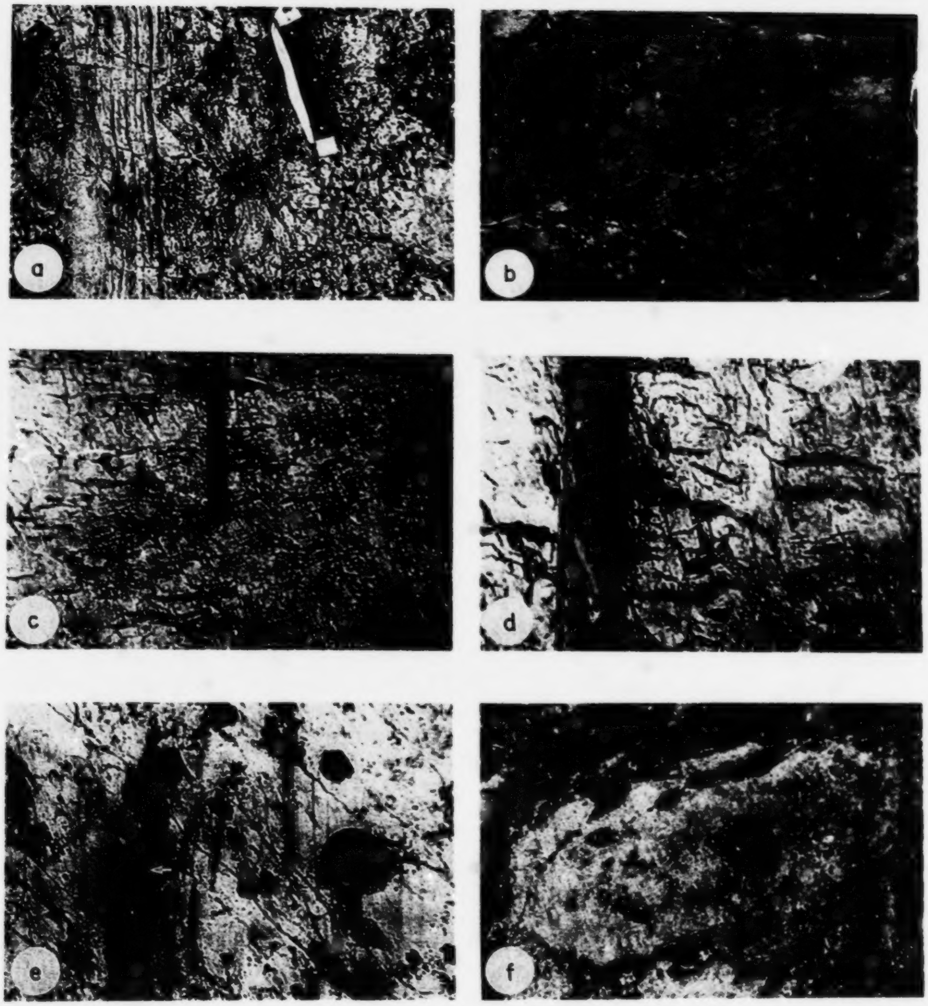

a
b
c
d
e
f

Photo 5a–Subaqueous ignimbrite, Cycle II, formation G, north bay of Narrow Lake. Rhyolitic tuff-breccia to lapilli-tuff on the right is overlain by fine-grained, finely bedded tuff. These represent deposition from a glowing avalanche and glowing cloud parts respectively of an ash flow.

Photo 5b–Subaerial ignimbrite, Cycle II, formation H, Woman Lake. Lower partly welded part of the lower of two flow units in the Woman Lake Tuff. The large square and the triangular clast are undeformed lithic fragments. Partly recrystallized pumice fragments from dark wavy areas draped around the lithic fragments; the light coloured matrix is glass-rich ash.

Photo 5c–Subaerial ignimbrite, Cycle II, formation H, Woman Lake. Upper densely welded part of the lower flow unit. Pumice, the dark clasts, is enriched in the upper part of the unit.

Photo 5d–Detail of Photo 5c showing the flame-like terminations on some pumice fragments.

Photo 5e–Woman Lake Tuff, Cycle II, formation H. Note mafic lapillus (to left of lens cap) in upper flow unit in upper welded zone.

Photo 5f–Woman Lake Tuff, Cycle II, formation H. Layer 3 of the upper flow unit has faintly bedded fine-grained lapilli-tuff forming in the uppermost part. Bedding trends from top to bottom of the photo to the right of lens cap.

TABLE 9 DETAILED STRATIGRAPHY OF THE WOMAN LAKE TUFF.

TOP	
12 m	unwelded felsic air-fall tuff, lapilli-tuff, minor tuff-breccia a) uppermost 1.5-3 m felsic tuff-breccia with 20-30% pumice, 10-15% lithic fragments, unbedded in ash matrix. b) lower 9-10 m air-fall tuff 6 to 8, 4 to 60 cm thick normally graded tuff with 3-5 mm feldspar and quartz grains and lithic clasts (25%) in an ash matrix.
4.5 m	unwelded felsic lapilli-tuff (20% pumice avg. 2 x 1 cm)
2 m	unwelded felsic lapilli-tuff a) uppermost 25-30 cm bedded parallel laminated ash b) 1.8 m felsic lapilli-tuff with 20-30% 2 x 2 cm pumice fragments.
50-120 m	welded felsic lapilli-tuff (unit 2) a) uppermost 0.2 m parallel bedded felsic tuff b) unwelded lapilli-tuff 2 m thick with 20-30% 1 x 2 cm pumice c) 47.8-117.8 m partly welded to welded felsic lapilli-tuff (a distinctive 1 m thick unit with 10% mafic lapilli occurs towards the top of this section).
50 m	welded felsic lapilli-tuff (unit 1) a) uppermost 3 m - up to 45 x 4 cm pumice clasts (50%) in an ash matrix. b) 47 m - 5 cm x 5 mm pumice clasts in an ash matrix with rare lithic clasts (clasts form 38% of middle part) c) a 30 cm thickness about 1 m above the base is locally vitrophyric.
1 m	unwelded felsic crystal lithic air-fall tuff thin-bedded (2-8 cm) normally graded with sparse lapilli.
BOTTOM	

TABLE 10 | SUMMARY OF MODAL DATA, WOMAN LAKE TUFF.

Proportions (in percent) of lithic fragments, pumiceous fragments, phenocrysts, and shards.

		Pheno-crysts	Lithic		Pumice		Glass		Number of Specimens
			Range	Mean	Range	Mean	Range	Mean	
Top:	Upper unwelded	—	Nil	—	60.0-100.0	80.0	40-00	20.0	3
	Upper partly welded	0.4	0.0- 7.0	3.0	33.0- 37.0	36.5	45-65	58.0	4
	Welded	2.6	7.0-20.0	13.0	30.0- 39.0	34.5	35-60	52.0	2
Base:	Welded	0.5	3.1- 3.6	3.5	21.1- 29.0	24.4	65-75	69.2	8
	Lower partly welded	0.8	17.6-45.5	31.6	3.1- 15.0	8.5	45-75	62.1	4
	Lower unwelded	0.9	11.0-27.9	19.1	5.0- 23.0	15.0	53-63	65.0	5

Size of lithic and pumiceous fragments:

			Largest	Smallest	Mean
Pumice:	Top:				
		Upper	40.0 x 3.0 cm	0.5 cm	2 cm
		Lower	7.0 x 2.0 cm	0.5 cm	3 cm
	Base:				
		Upper pumice-rich part	38.0 x 2.5 cm	0.05 x 1.0 cm	2.0 x 0.2 cm
		Remainder of unit	5.3 x 2.5 cm	2.0 x 0.3 cm	2 cm
Lithic:	Top:				
		Upper 100 m (avg.)	2 cm	0.2 cm	0.5 cm
		Lower 20-50 m (avg.)	3 x 2 cm	0.5 cm	0.5 x 0.8 cm
	Base:				
		Upper 40 m	20 cm	0.5 cm	0.8 x 0.5 cm
		Lower 10 m	2 cm	0.2 cm	1 cm

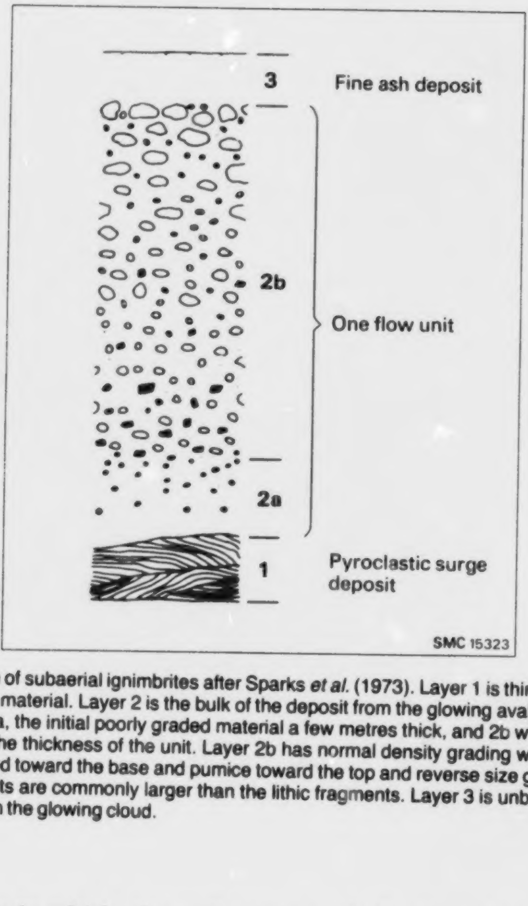


Figure 8–Subdivision of subaerial ignimbrites after Sparks *et al.* (1973). Layer 1 is thinly cross laminated base surge material. Layer 2 is the bulk of the deposit from the glowing avalanche, subdivided into layer 2a, the initial poorly graded material a few metres thick, and 2b which forms over 90 percent of the thickness of the unit. Layer 2b has normal density grading with lithic fragments concentrated toward the base and pumice toward the top and reverse size grading since pumice fragments are commonly larger than the lithic fragments. Layer 3 is unbedded fine tuff deposited from the glowing cloud.

the isolated area in which, the unit appears wholly glassy, is a basal vitrophyre. The conversion of the glassy matrix to coarser crystals of plagioclase and quartz in the central welded zone is considered, by analogy with younger units (Anderson 1969; Geijer 1913; Ross and Smith 1961; Snyder 1962) to be vapor phase recrystallization to T. Torske's (1975) snowflake texture. The foliation, present only in the matrix, which passes around lithic fragments is interpreted as eutaxitic foliation.

Granophyric intergrowths of albite and quartz in the welded zone of the Woman Lake Tuff represent granophyric recrystallization as described by R.L. Smith (1960). The relict glass-filled fractures perpendicular to strike confined to the upper part of the tuff are interpretable fumarolic alterations. The intensity of recrystallization and welding lead to the conclusion that the Woman Lake Tuff represents a subaerial ignimbrite (see Table 7).

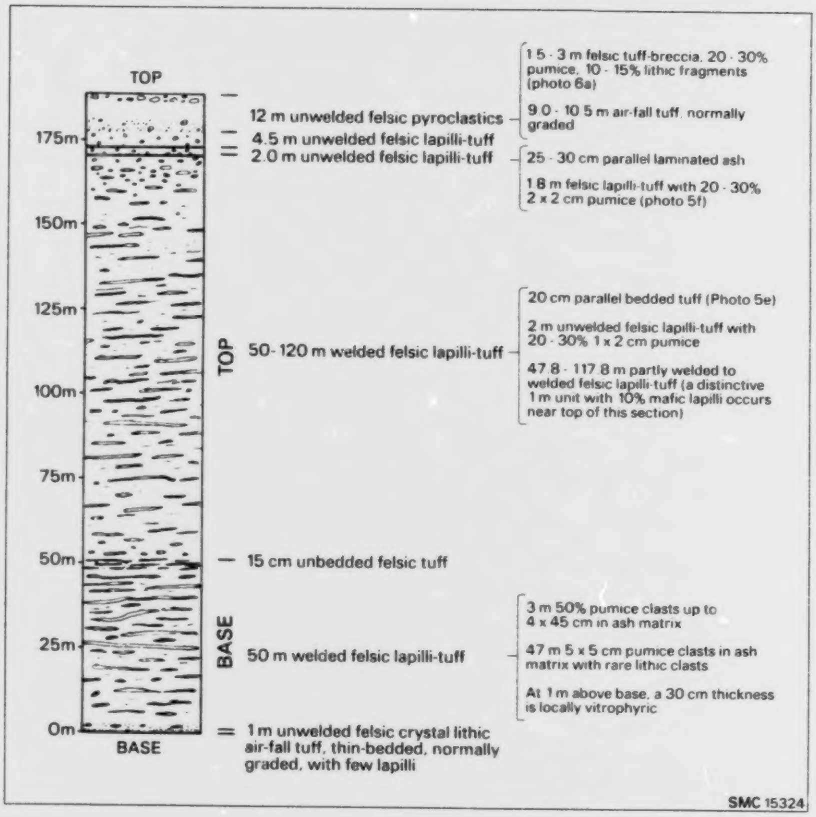

TOP
175m
150m
125m
100m
75m
50m
25m
0m
BASE
TOP
BASE
12 m unwelded felsic pyroclastics
4.5 m unwelded felsic lapilli-tuff
2.0 m unwelded felsic lapilli-tuff
50-120 m welded felsic lapilli-tuff
15 cm unbedded felsic tuff
50 m welded felsic lapilli-tuff
1 m unwelded felsic crystal lithic air-fall tuff, thin-bedded, normally graded, with few lapilli
1.5 - 3 m felsic tuff-breccia, 20 - 30% pumice, 10 - 15% lithic fragments (photo 6a)
9.0 - 10.5 m air-fall tuff, normally graded
25 - 30 cm parallel laminated ash
1.8 m felsic lapilli-tuff with 20 - 30% 2 x 2 cm pumice (photo 5f)
20 cm parallel bedded tuff (Photo 5e)
2 m unwelded felsic lapilli-tuff with 20 - 30% 1 x 2 cm pumice
47.8 - 117.8 m partly welded to welded felsic lapilli-tuff (a distinctive 1 m unit with 10% mafic lapilli occurs near top of this section)
3 m 50% pumice clasts up to 4 x 45 cm in ash matrix
47 m 5 x 5 cm pumice clasts in ash matrix with rare lithic clasts
At 1 m above base, a 30 cm thickness is locally vitrophyric
SMC 15324

Figure 9–Detailed stratigraphy of the Woman Lake Tuff.

East of Lost Bay, thin- and medium-bedded (0.5 to 30 cm) felsic tuffs, are intercalated with mafic flows and hyaloclastites giving an aggregate thickness of 106 m. Clast size grades uniformly upward within each bed. Some upper fine-grained parts of beds appear to grade into what appears to be chert, but microscopically (73-12-17-130) the chert is seen as very fine grained quartz, albite, and epidote, with grain size of 0.05 to 0.1 mm, in the same proportions as the coarser part of the bed. There are no relict shards and only a few angular lithic fragments. Bedding is defined by grain size changes and minor variation in the proportion of sericite and biotite. These are air-fall tuffs, based upon the presence of bedding, the uniform fining upwards character, and the lack of accidental fragments.

The uppermost 400 m of formation H on Lost Bay is dominantly felsic lapilli-tuff and tuff. Microscopically the rocks consist of angular fragments (see Photo 4e, 73-12-1010) and pumiceous lapilli. The angular relict glass fragments are now made up of very fine grained chlorite, epidote, and opaque iron-titanium oxide. The former pumiceous lapilli are characterized by wispy termi-

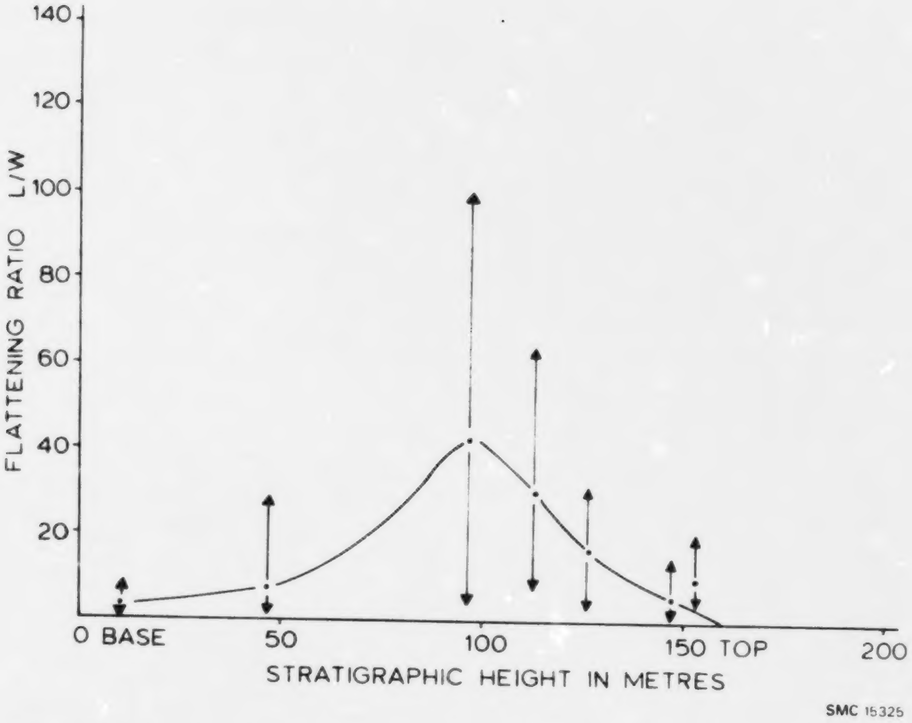


Figure 10–Length/width flattening ratio for pumice fragments in the Woman Lake Tuff versus stratigraphic position, indicating the greatest deformation toward the centre. Arrows indicate the range of the measurements, made after the method Peterson (1961) by Savory (1976).

TABLE 11 | TEXTURAL AND MINERALOGICAL CHANGES CAUSED BY WELDING IN THE WOMAN LAKE TUFF.

UNWELDED	PARTLY WELDED	WELDED	BASAL VITROPHYRE
MATRIX			
Ash: Relict shard shapes visible in plane light as elliptical irregular areas filled with secondary fine-grained quartz, feldspar, sericite, and epidote.	Relict shards flattened as in unwelded zone and bent around pumice and lithic fragments; replaced by similar secondary mineralogy	Shards not discernible. Replaced by development of fine oriented axiolites of quartz and feldspar. Cut by hair-line quartz-filled fractures perpendicular to bedding. Phenocrysts of granophyric intergrowths of quartz and albite in most highly welded zone.	Shards not discernible.
Phenocrysts: Abundant feldspar phenocrysts, subhedral, commonly broken, a few corroded quartz phenocrysts.	Broken subhedral feldspar phenocrysts. No change in quartz phenocrysts.	Phenocrysts extensively sericitized, rotated, and surrounded by a sericite-free halo 0.5 mm wide.	Not observed.
Lithic Fragments: 2 mm fragments, generally aphyric relict glass now fine-grained quartz and feldspar, concentrated toward the base of Units 1 and 2.	Unchanged from unwelded zone.	Some development of spherulitic textured feldspar clusters.	Not observed.
CLASTS			
Pumice: Lapilli and block size relict glass replaced by fine-grained feldspar, quartz, sericite, epidote, and chlorite. Relict vesicles may be filled with quartz, slightly flattened (Photo 6a)	Greater flattening (Figure 10). Replacement of relict glass by feldspar, quartz, sericite, and slightly greater amounts of epidote and chlorite than in unwelded zone. Shards in eutaxitic texture around pumice.	Extensive elongation of clasts replacement of relict glass by fine polycrystalline quartz development of fiamme morphology. (Thurston 1980a, Plate 1)	Entirely replaced by secondary mineralogy with clast boundaries obscured by recrystallization.
Lithic: Lapilli-size angular fragments. Relict glass with feldspar phenocrysts. Glass replaced by fine-grained secondary mineralogy as above.	Shards develop good eutaxitic foliation above lithic fragments. No textural change.	No textural change.	

nations and a foliation that may have formed after long tube vesicles and consist of very fine grained epidote and albite. The matrix is vermicular textured epidote, albite, and quartz after glass shards. Reverse grading and double grading similar to that in Yamada's (1973) sandy pumice-tuff division is visible in some outcrops. The thin-bedded felsic tuff is common in the east-facing part of Cycle II on the west shore of Uchi Lake.

Formation J

Formation J is above the Woman Lake Tuff of formation H and consists of 60 m of finely laminated (0.5 to 10 mm thick) calcite, with interbeds of quartz and organic-rich silty material now composed of black opaque material and tremolite-actinolite. Areas of coarse (2 to 5 mm), recrystallized calcite form irregular knots not exceeding 10 percent of the rock. The wavy form of the carbon-rich laminae is assumed on the basis of its form and distribution to mark the presence of stromatolites (cf. Henderson 1975; H. Hoffman, Department of Geology, University of Montreal, personal communication, 1980), (Photo 6b).

CYCLE III

Formation K

Cycle III, the youngest of the three cycles, is exposed on both limbs of the regional synclinorium (see map, back pocket). On both limbs, mafic flows and associated coarse-grained intrusive rocks of formation K form the base of the cycle, and are 3400 to 5500 m thick. On the west limb the formation is traceable for 31.4 km, from the south to the north boundary of the area and is known to extend a further 1.8 km north to the Swain Lake Fault. The southern limit has not been well defined (Breaks *et al.* 1975). On the east limb of the regional synclinorium, formation K is 2250 m thick and extends from Fly Lake in the south to the Swain Lake Fault, a distance of 37 km. It is underlain by felsic tuffs and the stromatolitic carbonate which forms the upper part of Cycle II, and is overlain by intermediate and felsic pyroclastic rocks of formation L, Cycle III and by formation M at Fly Lake.

The weathered surface of formation K varies in colour from dark to light green to white and is dark green or light green to white on fresh surface. Its lower part consists of pillowed flows, assumed to be relatively thin inasmuch as no massive flow centres are present. Individual flows up to 60 m thick are in outcrops on the shore of Lost Bay of Confederation Lake. Pillows are elliptical to bun-shaped with 1 to 4 cm thick selvages. Commonly they contain small (1 to 2 mm) plagioclase phenocrysts and microspherulitic quartz and plagioclase intergrowths (2 to 3 mm) in a relict glass matrix. Amygdules form about 20 percent. Chert and spalled glass fragments form interpillow debris (Photo 6f). Broken and isolated pillow breccia (Carlisle 1963) occurs as irregular bodies 90 m thick with minimum lengths of about 150 m at scattered localities on Lost Bay. Textures in the massive flows are ophitic to intergranular, isogranular (Oppenheim 1964), or variolitic.

A variolitic part up to 90 m thick, possibly a single flow, occurs 460 to 580 m above the base of formation K. This has a lateral extent of at least 14 km from Fly Lake to the southern contact of the Okanse Batholith on the east limb of the regional synclinorium and, about 16 km on the west limb. Varioles average 1.5 cm in diameter and range from 0.5 to 5 cm; they form 20 to 100 percent of the rock. They have a vitreous white centre set in a dark brown fine-grained mafic matrix. As they become more abundant they coalesce (Photo 6d) and form layers up to 2 m thick. Variations in the abundance of the varioles indicate some type of flow differentiation (Photo 6c).

Individual varioles commonly have an intensely saussuritized outer rind, 1 to 2 mm thick, surrounding a core of alternating acicular albite and quartz with branching intergrowths of clinozoisite arranged in radial patterns (Photo 6c). Toward the rim, the varioles have greater concentrations of clinozoisite, and minor chlorite, biotite, carbonate, and leucoxene. The central core of the varioles generally consists of medium-grained anhedral quartz, sericite, and carbonate with a polygonal texture (Photo 6e). The variole to matrix boundary is sharp.

Common in this rock type are quench textures in the form of skeletal clinozoisite, perhaps after calcic plagioclase (cf. Gélinas and Brooks 1974), belt-buckle feldspars, and swallow-tail microlites. Coarse branching dendritic aggregates of quartz and albitic plagioclase give way outward from the centres of the varioles to radiating acicular crystals surrounded by clinozoisite- and chlorite-rich border zones. The matrix consists of a felted mass of chlorite needles after quench pyroxenes, and relict plagioclase (cf. Bryan 1972; Gélinas and Brooks 1974).

On the basis of the large size of the varioles, the lack of association with pillow rims, their irregular shape, and apparent contrast in composition between variole and matrix, the variolites correspond to the Blake River type of L. Gélinas *et al.* (1976).

The white weathering, white fresh surface parts of formation K are distinguished from felsic flows by the presence of pillows, greater density, lack of conchoidal fracture, massive appearance, and lack of quartz in the weathered rind. They contain more than 25 percent epidote, whereas epidote is less abundant in felsic flows.

Plagioclase is uniformly albitic and contains small (0.01 to 0.03 mm) subhedral light green grains of epidote which make up a maximum of 30 percent of the albite grains; alternatively epidote is in very fine (0.01 mm) anhedral granules which form 90 to 100 percent of plagioclase grains. The ferromagnesian minerals present vary from coarse anhedral poikilitic plates of augitic clinopyroxene, 5 to 10 mm in size, to coarse (5 mm) poikiloblasts of feathery tremolite-actinolite, and chlorite. Chlorite is rarely the dominant ferromagnesian mineral. Carbonate is present in some samples replacing other phases or randomly forming 1 to 3 mm anhedral grains. More commonly it is confined to veins, or is present in amygdules with quartz rims and carbonate cores. Other phases present in veinlets include epidote, quartz, stilpnomelane, biotite, and sericite.

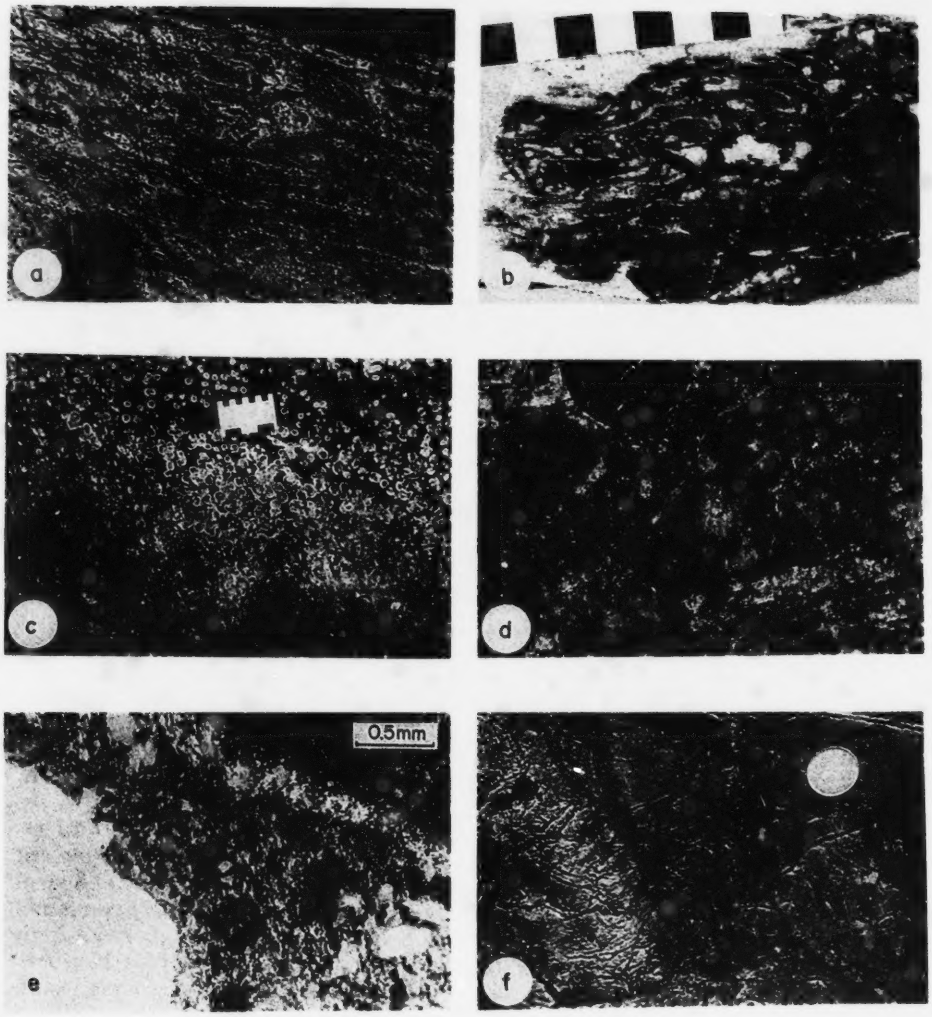

a
b
c
d
0.5mm
e
f

Photo 6a–Subaerial ignimbrite, Cycle II, formation H, on Woman Lake. Upper unwelded part of the upper flow. Relatively undeformed, unrecrystallized rhyolite pumice fragments outlined by wispy chlorite.

Photo 6b–Hand specimen of stromatolitic carbonate, formation J, capping Cycle II on Woman Lake. White areas on sparry recrystallized carbonate, dark curved linear elements are fine-grained carbonate and organic material. Scale card marked in centimetres.

Photo 6c–Varioles in a massive intermediate flow unit with no discernible pillow structure. Varioles are light coloured rounded bodies. Lighter rim is a metamorphic phenomenon. Cycle III, formation K.

Photo 6d–Coalescence of varioles is seen in detail here, coin is 25.5 mm in diameter.

Photo 6e–Cycle III, formation K. Varioles including a plucked out vesicle in lower left, and the matrix in the upper right. Note the sharp contact between variole and matrix. Specimen 77-450, crossed polars.

Photo 6f–Basalt, Cycle III, formation K, Lost Bay. Spalled relict glass filling the interpillow space.

In the lower part of formation K, on Bobjo Point of Confederation Lake, flows are present with light green to white fresh surface. They are composed of an epidote-rich assemblage consisting of 40 percent zoisite and clinozoisite, 40 percent albite, 15 percent tremolite-actinolite, and 5 percent carbonate, with trace amounts of chlorite. Carbonate is more abundant in interpillow spaces and on the outermost 4 to 5 cm of individual pillows. The pillow interiors consist of chlorite, tremolite-actinolite, and albite. Plagioclase contains small (0.01 mm) scattered grains of epidote, and large (0.1 to 0.3 mm) anhedral flakes of zoisite appear to replace most of the ferromagnesian minerals. There is up to 20 percent chlorite or tremolite in some examples. Carbonate content varies from trace to 15 percent as anhedral grains replacing earlier phases or filling amygdules.

In the Setting Net Lake area, Ayres has noted (L.D. Ayres, University of Manitoba, personal communication, 1974) pods, veins, and areas of pervasive epidote, quartz, and magnetite (with or without pyroxene) alteration in mafic flows beneath impermeable chert beds. This phenomenon increases in intensity as the chert is approached. Ayres attributes it to hydrothermal or fumarolic alteration, beneath the impermeable chert cap rock. Water-dominated greenschist facies alteration of oceanic basalt described by S.E. Humphris and G. Thompson (1978) produces similar epidote-rich assemblages. The widespread distribution of the epidote-rich assemblages throughout formation K, and the lack of epidotized mafic flows in formations A and E, supports the interpretation that this alteration assemblage was produced prior to regional metamorphism.

Formation L

Formation L extends from east of North Bay of Confederation Lake southward to Fly Lake and beyond out of the map area, a distance of 30 km; the thickness is approximately 2000 m (see Figure 3, Chart A, back pocket). It is dominantly tuff with minor intercalated flows. The tuff units are intermediate to felsic in composition (mean $SiO_2 = 67$ percent, $n = 18$; V.J. Sopuck, Saskatoon Research Council, Saskatoon, Saskatchewan, personal communication, 1976) and differ from the overlying coarse-grained felsic tuff and flows of formation M in that they are relatively fine, glass-rich, and contain common devitrification spherulites (Lofgren 1971b; Kesler and Weiblen 1968).

Intermediate flows are dominant at the base of formation L, and lighter weathering felsic, dominantly pyroclastic rocks, in its upper part. In general the rocks have a black through light green or grey weathered surface and a white to black fresh surface. Intermediate flows occur in the vicinity of Mukukee Lake in Agnew Township and along the shore of the bay on the west side of Lost Bay of Confederation Lake. The flows are massive to slightly foliated in hand specimen with scattered spherulites which vary in size from 1 mm to 2 cm. No pillows were observed. The flows have an intergranular texture (Oppenheim 1964) with the mineral assemblages listed in Table 12. Relict primary albite phenocrysts are clouded with 0.01 mm subhedral grains of epidote scattered throughout. The ferromagnesian minerals are chloritic aggregates which

TABLE 12 METAMORPHIC MINERAL ASSEMBLAGES IN INTERMEDIATE METAVOLCANICS, EARNGEY-COSTELLO TOWNSHIPS.

Amphibolite Facies

- Plagioclase, hornblende, quartz, biotite, epidote, chlorite, tremolite
- Hornblende, biotite, quartz, plagioclase, cummingtonite
- Plagioclase, hornblende, epidote, chlorite, carbonate, quartz, biotite
- Plagioclase, hornblende, chlorite, epidote, quartz, biotite
- Plagioclase, hornblende, quartz, chlorite, biotite, epidote, carbonate
- Plagioclase, hornblende, quartz, chlorite, epidote, biotite.

Greenschist Facies

- Albite, tremolite, biotite, chlorite, muscovite
- Albite, chlorite, carbonate, biotite, epidote
- Albite, tremolite, epidote, biotite, chlorite, carbonate
- Albite, epidote, chlorite, biotite, muscovite, K-feldspar
- Albite, biotite, epidote, carbonate
- Albite, tremolite, epidote, carbonate
- Albite, chlorite, sericite
- Biotite, epidote, albite, carbonate, chlorite, tremolite
- Biotite, albite, epidote, stilpnomelane

All assemblages are quartz-bearing.

make up 15 to 25 percent of the rock. Fine-grained generally interstitial 1 to 2 mm plagioclase euhedra (73-12-2713) form the mesostasis.

The pyroclastic rocks are intermediate to felsic tuff and lapilli-tuff with minor tuff-breccia. Typically, the outcrop surfaces show alternating beds of aphanitic black weathering material which is fine-grained glassy tuff, and fine-grained sandy textured coarse tuff. Spherulites are common throughout (Photo 7a). The rock (73-12-2481) consists of 1 to 5 mm subangular lithic fragments of quartz, albite, chlorite, biotite, sphene, and epidote, surrounded by relict pumice fragments composed of very fine grained (0.02 mm) biotite, chlorite, epidote, and lenticles of quartz and albite. Pumiceous fragments typically 5 to 10 mm long by 2 to 3 mm wide have ragged terminations and form up to 20 percent of the rock. The texture is eutaxitic as there is evidence of compaction and partial welding (cf. Ross and Smith 1961).

Some tuffs contain large spherulites up to 1 cm in diameter; the spherulites are concentrated in 1 to 5 cm thick beds separated by spherulite-free beds of similar thickness. Spherulites consist of radiating, very fine grained (0.01 mm), acicular albite, quartz, and epidote in a matrix of albite, quartz, biotite, and epidote consisting of fingerprint-like swirls. Epidote, biotite, quartz, and albite are interpreted to be devitrification textures (cf. Ross and Smith 1961). Masses consisting of greater than 90 percent epidote, quartz, biotite, and stilpnomelane between spherulites are also interpreted as a devitrification phenomena. The spherulites generally have smooth elliptical outlines suggesting they were not produced by the low temperature vapor phase crystallization phenomenon which produces irregularly shaped spherulites in ignimbritic rocks (Ross and Smith 1961) (73-12-2886); rather they represent conventional devitrification processes.

Along the west shore of Mukukee Lake in Agnew Township over a thickness of about 300 m and a lateral extent of about 6 km, formation L includes a large proportion of tuff-breccia featuring highly epidotized fragments. The tuff-breccia consists of 10 to 40 percent rounded clasts averaging 15 to 20 cm in long dimension, and 60 to 90 percent glass-rich crystal tuff with a few pumiceous fragments. Clast matrix contacts vary from sharp to gradational suggesting a post-depositional alteration event. The matrix consists of spherulitic tuffaceous material similar to that described above, with up to 10 percent broken quartz phenocrysts. The bedding thickness, 1 to 2 m thick, in combination with the presence of pumiceous fragments, suggest that this rock represents a subaqueous ash flow (cf. Parsons 1969, p.298-300).

Formation M

Most of formation M is in a fault-bounded block which trends in a northward direction from the southern edge of the map area to slightly north of South Bay Mine, a distance of 16 km. This formation is equivalent to the 'Mine Series' of Sopuck (1977). The structural trend of lithologies outside the block is generally northward. Within the block northeast trends predominate. Minor occurrences of north-trending felsic tuff occur east of the fault-bounded block. Formation M, the top of the stratigraphic section, is underlain by the intermediate to felsic metavolcanics of formation L and rarely by formation K, Cycle III. Thickness is difficult to estimate as marker beds have only limited extent but maximum thickness is estimated at 2200 m (Thurston 1979).

The felsic metavolcanics of formation M include about 1500 m of rhyolite flows and associated hyaloclastite and brecciated flows (terminology of Dimroth and Rocheleau 1979) succeeded upward by about 1000 m of tuff, lapilli-tuff, and tuff-breccia considered to be dominantly ignimbritic, and 150 m of debris flows and air-fall pyroclastic rocks, capped by 45 m of mafic flow (Figure 11). Above this mafic flow there is a complex of mainly felsic flows and local ac-

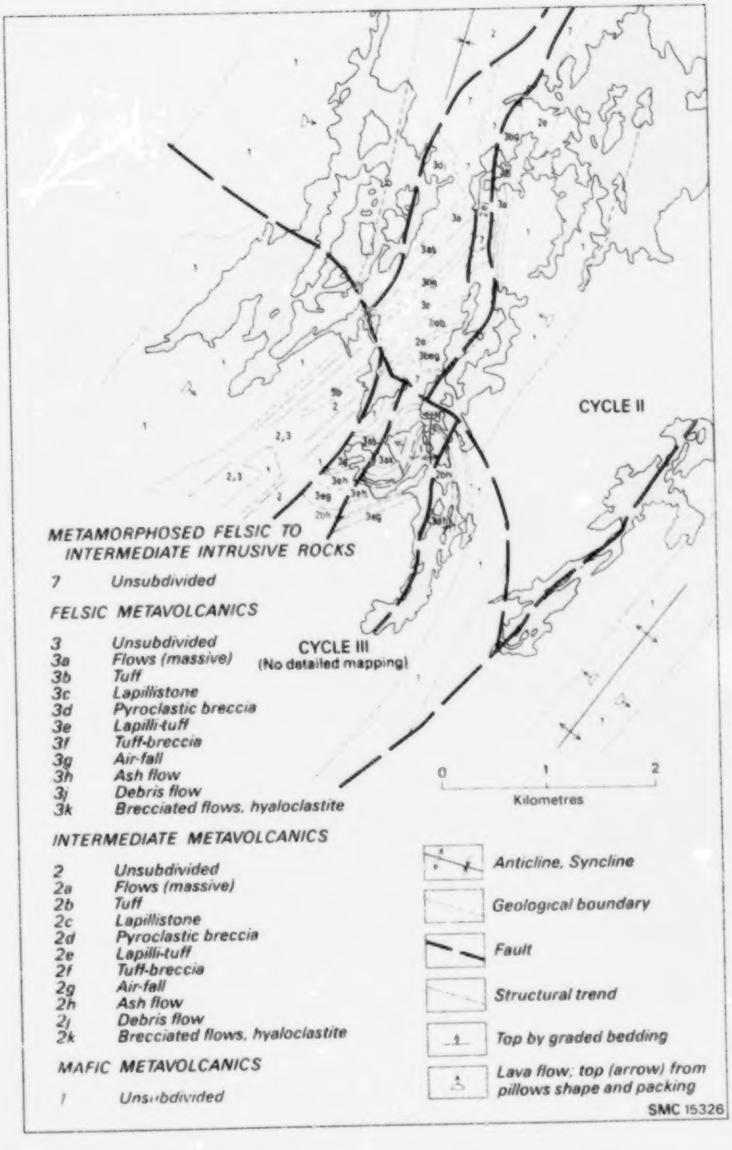

CYCLE II
CYCLE III
(No detailed mapping)
METAMORPHOSED FELSIC TO INTERMEDIATE INTRUSIVE ROCKS
7 Unsubdivided
FELSIC METAVOLCANICS
3 Unsubdivided
3a Flows (massive)
3b Tuff
3c Lapillistone
3d Pyroclastic breccia
3e Lapilli-tuff
3f Tuff-breccia
3g Air-fall
3h Ash flow
3j Debris flow
3k Brecciated flows, hyaloclastite
INTERMEDIATE METAVOLCANICS
2 Unsubdivided
2a Flows (massive)
2b Tuff
2c Lapillistone
2d Pyroclastic breccia
2e Lapilli-tuff
2f Tuff-breccia
2g Air-fall
2h Ash flow
2j Debris flow
2k Brecciated flows, hyaloclastite
MAFIC METAVOLCANICS
1 Unsubdivided
0
1
2
Kilometres
Anticline, Syncline
Geological boundary
Fault
Structural trend
Top by graded bedding
Lava flow; top (arrow) from pillows shape and packing
SMC 15326

Figure 11–Pyroclastic rocks in the sector graben, Cycle III.

cumulations of pyroclastic rocks interpreted as a collapsed endogenous dome at the South Bay Mine (Pollock *et al.* 1972). The approximate boundary between the interpreted dome of South Bay Mine and the ignimbrites to the south is the north end of Fly Lake (Figure 11).

Weathered surfaces in formation M vary from light green through grey and white. Fresh surfaces are grey to white. Generally most rocks are aphanitic, although quartz can be observed in the weathered rind. Mineral assemblages in the felsic metavolcanics are largely secondary (see Table 8). Saussuritized primary plagioclase occurs as 5 to 10 mm phenocrysts in the quartz-feldspar porphyry at the South Bay Mine.

Fine-grained felsic tuff with bedding from 2 to 3 cm thick occurs in the vicinity of the quartz-feldspar porphyry dome and farther south along the west shore of Fly Lake. The tuff consists of 0.1 to 1 mm grains of angular to subangular quartz and albite with minor interstitial chlorite, white mica, albite, and epidote. Bedding, where it can be seen, in the tuff is planar. South of the mine, fine-grained tuff is interbedded with lapilli-tuff (Photo 7b) which consists of one half to two thirds ash matrix and millimetre to centimetre size complex amoeboid-shaped fragments in varying proportions. As these fragments are irregularly shaped and some have more intensely saussuritized rims relative to their centres, the author interprets them to have been hot glassy fragments derived from underlying felsic flows (cf. Dimroth 1975), (Photo 7d).

Many fine-grained felsic tuffs consist of alternating beds of relict glass lenticles (0.2 by 0.01 mm) in 1 to 2 cm thick beds separated by beds of relict glass and pumiceous fragments up to 1 to 2 mm in size. The formerly glass-rich beds contain 10 to 40 volume percent of spherulites, 2 to 5 mm in diameter, composed of acicular quartz and albite, separated by a matrix of chlorite, sericite, and epidote. Development of spherulites in glass-rich volcanic rocks is a reasonably rapid process at elevated temperatures (Kesler and Weiblen 1968), taking on the order of 1 to 2 days at 900°-1000°C for andesitic glasses. The slower diffusion rate in rhyolitic glass relative to the andesitic glasses referred to by S.E. Kesler and P.W. Weiblen and the lower temperature involved in these air-fall deposits probably would not radically increase the time necessary for their formation.

Massive and porphyritic felsic flows are close to the quartz-feldspar porphyry dome and to the south along Fly Lake. The flows have a massive to porphyritic interior overlain by autoclastic breccia. This breccia consists of 0.1 to 0.5 mm angular lithic fragments composed of fine-grained quartz, albite, and sericite, in a matrix of straight-sided fragments with similar mineralogy assumed to be hyaloclastic in origin (cf. Macdonald 1972, p.105). Stratiform spherulitic zones are associated with crackle brecciated flows in the mine area. Felsic flows in the Fly Lake area are generally massive, commonly with 1 to 5 mm quartz and albite phenocrysts in a fine-grained quartz, albite, sericite groundmass. Irregular spherulite-rich zones are interspersed with massive parts of flows. The spherulites are surrounded by light brown weathering epidote-rich relict glass. Flow banding presently consisting of 0.5 to 2 cm spaced parallel healed cracks representing perlitic fractures is observed in a few outcrops at Fly Lake.

The units in formation M interpreted as ignimbrites typically consist of tuff-breccias to lapilli-tuffs 10 to 20 cm thick. A peculiar rock on an island in the southern part of Fly Lake is felsic tuff-breccia containing 40 percent angular to rounded felsic lithic fragments generally with very irregular shapes resembling fusiform bombs (cf. Macdonald 1972, p.127). These fragments are in a matrix composed of small (10 to 15 mm), angular to subangular essential felsic lithic fragments, 20 percent pumiceous fragments, and ash-size material. Rims, 0.5 to 1 cm wide, on the larger fragments are lighter coloured than the fragment interior.

In a typical exposure from this area, layer 1 of Sparks *et al.* (1973) (see Figure 8) is not found. Layer 2a, 0.5 to 0.8 m thick, consists of 20 to 30 percent pumiceous essential felsic lapilli and blocks, and 5 to 10 percent essential felsic lithic fragments in a felsic ash matrix. This is succeeded upward by layer 2b of Sparks *et al.* (1973), consisting of 20 to 50 percent essential pumiceous felsic bombs, commonly subrounded but may be angular, in a matrix of 20 percent lapilli of felsic pumice and 80 percent felsic tuff. Reverse size grading is commonly conspicuous with the uppermost 0.3 m of a 3 m thickness consisting of more than 75 percent pumiceous bombs 0.2 to 0.3 m in size. Layer 3 of Sparks *et al.* (1973) is generally present, about 15 m thick and unbedded.

The layers show reverse size grading of pumiceous fragments, and have pumice-rich tops. Normal density grading of the relatively scarce lithic fragments is discernible near the base. These points plus the lack of stratification, and the poor development of welded textures in pumiceous fragments suggest the rocks are ignimbrites (cf. Sparks *et al.* 1973).

The 152 m thickness of air-fall tuff and debris flows above the ignimbrite consists of (1) heterolithic intermediate to felsic lapilli-tuff to tuff-breccia and (2) well bedded felsic tuff. The coarse pyroclastic rocks contain subrounded intermediate and felsic pumiceous and lithic fragments of many rock types with no sign of welding, size grading, density grading, or bedding. Sand-size clastic quartz, chlorite, and feldspar form a fine matrix constituting 10 to 15 percent of the rock. On the basis of the heterolithic character, the scant matrix, and the lack of primary structures, it is considered a lahar (cf. Mullineaux and Crandell 1962).

A 3 to 6 m thickness of well-bedded felsic tuff containing less than 5 percent rounded felsic lithic bombs about 20 cm in long dimension caps the felsic sequence. Bomb sag structures and the bedded nature of the unit suggest it is an air-fall tuff.

Coarse pyroclastic rocks of intermediate composition occur just east of South Bay Mine at Lost Bay on Confederation Lake (77-428). There a coarse breccia consists of 10 to 20 percent angular to subangular scoriaceous fragments up to 15 cm (average 7 to 10 cm), 60 percent angular bomb and lapilli-sized lithic fragments, and 20 to 40 percent matrix of lapilli-tuff and tuff containing 3 to 10 mm subangular fragments. Fragments and matrix are of the same composition, with a tendency for fragments to be slightly more chloritic. The breccia is unsorted and unbedded over thicknesses of 10 m in individual exposures which occur intermittently over 300 m of stratigraphic thickness. The unit is lenticular, with a thickness of 550 m, and thins rapidly over 1 km northward and 2 to 5 km southward. The monolithic character of the fragments and matrix, lack of bedding, limited lateral extent, lack of interbedded fine-grained tuffaceous rocks, lack of accidental fragments, and close spatial relationship to the endogenous dome of quartz-feldspar porphyry at the South Bay Mine sug-

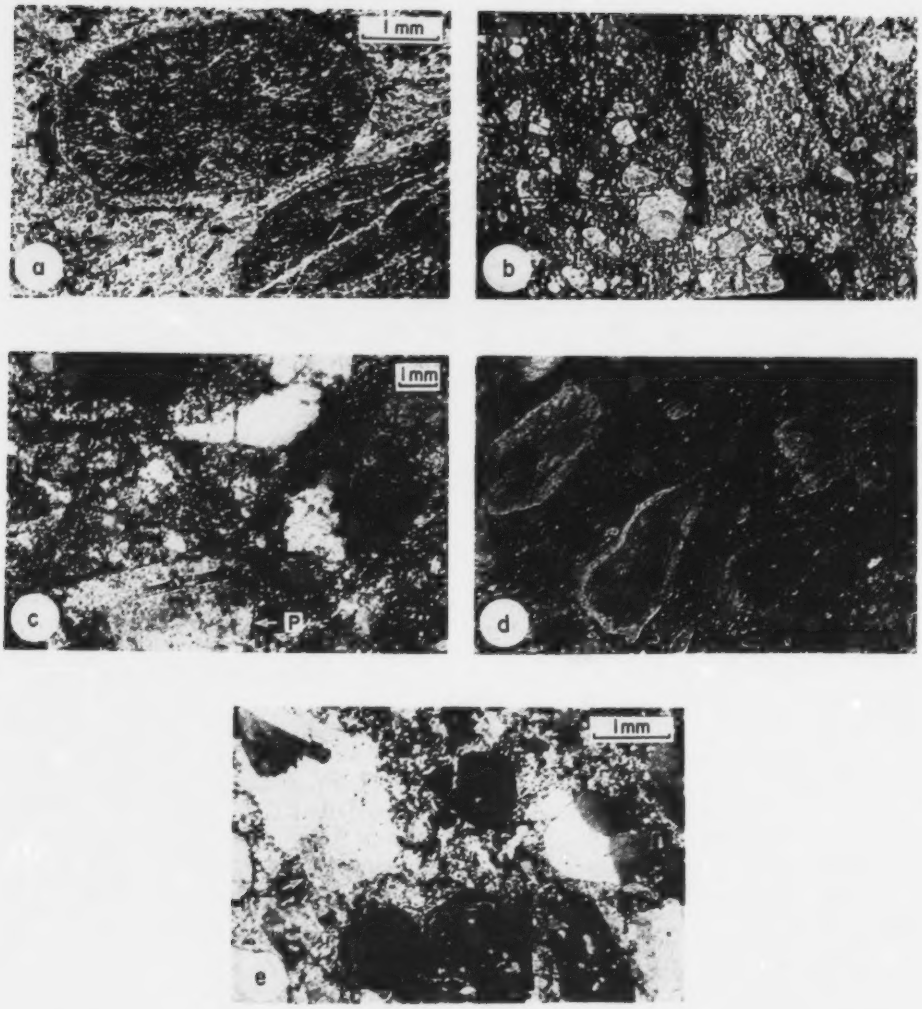

1 mm
a
b
1mm
c
P
d
1mm
e

Photo 7a–Felsic pyroclastic rocks, Cycle III, formation L, Mukukee Lake. Spherulite in a spherulitic felsic tuff. Spherulite is radiating albite, epidote, and quartz with minor sericite. The matrix, formerly glass shards, has the same mineralogy with a higher colour index. Specimen 73-12-2481, crossed polars.

Photo 7b–Felsic lapilli-tuff, Cycle III, formation M, on Confederation Lake south of the South Bay Mine.

Photo 7c–Quartz-feldspar porphyry forming the endogenous dome at the South Bay Mine. The plagioclase phenocryst in the lower left is somewhat sericitized and quartz phenocrysts are strained. The matrix is sericite, epidote, albite, and quartz.

Photo 7d–Felsic pyroclastic rocks, Cycle III, formation M, on Fly Lake south of the South Bay Mine. Note the light coloured rim on the larger fragments. The matrix is not ash but progressively smaller fragments. The unit is interpreted as pyroclastic fall back breccia or a subaqueous ash flow.

Photo 7e–Granophyric granodiorite, map unit 7d. A granophyric plagioclase and quartz occur in the upper left surrounded by quartz and feldspar phenocrysts in a fine-grained groundmass of quartz, feldspar, epidote, biotite, and amphibole.

gest that this formed as a dome-collapse breccia (cf.Parsons 1969, p.273, 299).

In summary, formation M consists in the north largely of flows and a dome-collapse breccia associated with a quartz-feldspar porphyry dome. In the south, it is made up of ash flow deposits succeeded upward by air-fall tuffs.

Geochronology

A Cycle III porphyritic felsic flow from the east shore of Fly Lake in Mitchell Township outside the fault-bounded block was sampled by the author and P. Nunes of the Royal Ontario Museum for U/Pb geochronology on zircons. An age of 2739 Ma ± 52 has been determined for this material (Nunes and Thurston 1980). Although slightly discordant, a sufficient number of points are available to suggest that this represents the age of crystallization of this rock.

A radiometric age determination by the U/Pb method on zircons from the rhyolite porphyry endogenous dome from the South Bay Mine within the fault-bounded block is 2740 Ma +. This is believed to be the age of crystallization of the porphyry based upon recalculation of the 2800 Ma age in T.E. Krogh and G.L. Davis (1971) using the newer decay constants.

Structural interpretation suggests that rocks within the fault-bounded block are younger than rocks outside the block. Therefore, the zircons of the porphyry are inherited, or the age on the porphyry body has a larger error associated with the data than the more recent analyses.

METAMORPHOSED FELSIC TO INTERMEDIATE HYPABYSSAL INTRUSIONS

A variety of rock types, varying in composition from granitic to quartz diorite, occur as small hypabyssal stocks, sills, and minor dikes. They generally cut formations of Cycle III. Characteristically their feldspars feature exsolution textures, and the more siliceous types are distinguished from their extrusive equivalent by more abundant sericite and extrusive textures.

Hornblende Quartz Diorite

A sill of hornblende quartz diorite occurs on Uchi Lake at the mouth of Leg Creek. The stock is intrusive into formation A and the metamorphosed diorites of map unit 6 which intrude formation A on the map. This stock covers an area of about 1.25 km^2. It extends roughly parallel to strike over a distance of 3.3 km and varies in width from 213 to 365 m. The sill weathers black to dark brown, and the fresh surface is generally dark green to black to dark brown. It contains 10 percent phenocrysts of quartz up to 2 to 3 mm in size, 10 to 15 percent plagioclase phenocrysts and 20 to 30 percent ferromagnesian phenocrysts less than 1 mm in size. They occur in a fine-grained groundmass. The proportions of ferromagnesian phenocrysts vary irregularly throughout the stock from two thirds biotite, one third hornblende to entirely hornblende. The hornblende-rich part of the rock hosts 25 to 30 percent slightly chloritic hornblende phenocrysts, 20 percent phenocrysts of saussuritized, granophyric plagioclase, and 10 percent phenocrysts of anhedral quartz (Photo 7e). The fine-grained groundmass is granophyric plagioclase and quartz, with minor epidote, carbonate, opaques, and about 1 percent scattered flakes of stilpnomelane. Texturally this rock is dominated by a preferred shape orientation of ferromagnesian minerals and plagioclase laths.

Granophyric Granodiorite

This rock name was used by A.P. Pryslak (Selco Exploration, Winnipeg, Manitoba, personal communication, 1973) to describe a number of metamorphosed felsic stocks in Dent and Mitchell Townships. Within the map area, the term is applied to grey to buff weathering felsic rocks consisting of 1 to 2 mm plagioclase phenocrysts in a fine phaneritic to aphanitic groundmass. At the north end of Found Lake in Agnew Township it is intrusive into formation K, and on the small peninsula at the north end of this lake, it is cut by granitic rocks of the Okanse Batholith. The major difference between this rock and the quartz-feldspar porphyry dome at South Bay Mine is the lower concentration of quartz phenocrysts in the former.

The major occurrences of this rock type are: (1) a stock 4.8 km long by 390 m wide, east of the south end of Fly Lake, and 670 m wide just south of the channel between Lost Bay and the main part of Confederation Lake; (2) a complex, multi-phase stock east of Found Lake in Agnew Township which consists of a more mafic, that is, dioritic phase and granophyric granodiorite; and (3) a sill which extends from the west shore of Lost Bay northward for 24.6 km to a point west of Found Lake with a width ranging from 180 m to 400 m.

The rock consists of 50 percent granophyric intergrowths of optically continuous plates and vermiform pods of quartz, with plates and long sinuous areas of sericitized albite. An additional 40 percent consists of 1 to 2 mm phenocrysts of saussuritized plagioclase and quartz in a matrix of optically continuous quartz (Photo 7e). Five to ten percent of the rock is sericite, biotite, and opaque iron-titanium oxides all interstitial to intergrowths of quartz and feldspar.

Some phases of the granophyric granodiorite, in particular the southern part of the stock east of Fly Lake and large parts of the Found Lake stock, have less than average quartz phenocryst content and two generations of plagioclase phenocrysts. Plagioclase laths about 2 by 0.3 mm comprise between 5 to 10 percent of the rock, and a second group of phenocrysts varying from 0.6 to 1 mm by 0.2 mm form about 60 percent of the rock. The latter phenocrysts have saussuritized central zones with 0.01 to 0.02 mm clear albite rims. Potassic feldspar grains about the same size as the smaller plagioclase grains form 10 percent of the rock. Finer anhedral grains of quartz and albite form most of the matrix which constitutes about 15 percent of the rock. The remainder is aggregates of chlorite, minor biotite, opaque iron oxides and sericite.

In general, the colour index and the type of ferromagnesian minerals in the granophyric granodiorite varies with the rock types which it intrudes. At the north end of the Fly Lake stock the accessory minerals are 5 percent muscovite with minor biotite, and here the rock is intrusive into intermediate and felsic metavolcanics. The south end of this stock is surrounded by mafic flows of formation K, and correspondingly the colour index increases from 5 to 15, and the ferromagnesian minerals are chlorite and minor biotite. The sill, which extends north from Lost Bay to west of Found Lake in Agnew Township, is almost wholly chloritic granodiorite. About 20 percent of the rock consists of sericitized plagioclase and quartz phenocrysts averaging 1 by 0.1 mm but in places as large as 2 to 3 mm by 0.2 mm, in a matrix of granophyric plagioclase, potassic feldspar, quartz, chlorite, and opaque iron oxides. Within the base of the sill there are two 30 m thick lenses of quartz-feldspar porphyry. At its north end the base of the sill contains a similar 30 by 490 m sill of quartz-feldspar porphyry. Small sills of quartz-feldspar porphyry are also found toward the top of the sill at the north end. The quartz-feldspar porphyry appears to be slightly later than the granodiorite.

The chloritic granophyric granodiorite in the sill consists of 10 to 15 percent 2 to 3 mm quartz phenocrysts, and 10 to 15 percent equant to subhedral sericitized plagioclase phenocrysts of similar size. These are generally rimmed by myrmekitic intergrowths of quartz and albitic plagioclase in a matrix of plagioclase, quartz, potassic feldspar, chlorite and opaque iron oxides.

Porphyritic Rhyolite

This rock, locally known as (Thurston *et al.* 1974; Pryslak 1971a) quartz-feldspar porphyry is a siliceous, intrusive rock, which is spatially associated with the Cycle III metavolcanics. Its principal features are abundant (20 to 40 percent) quartz phenocrysts, 0.06 to 0.2 mm in diameter, and generally subordinate amounts (10 to 15 percent) of albite phenocrysts, of similar size, in grey to white weathering massive to slightly foliated matrix. Scattered through this matrix, especially in the less altered varieties, there is 10 percent 0.1 mm rounded euhedral feldspar phenocrysts and trace amounts of 0.1 mm grains of epidote (Photo 7c). Secondary calcite cements fractured quartz phenocrysts.

A major occurrence of this rock type is a 122 m thick sill which extends for 1600 m along the west shore of Asin Bay of Fly Lake. An extension of this sill offset right-laterally, is continuing southward. A small sill 1220 m long by 120 m wide occurring 300 m south of the northwest corner of Earngey Township exhibits a chilled, phenocryst-free margin and is intrusive into metavolcanics.

These sills are spatially related to a large dome-like body of rhyolite porphyry in Dent Township, called the Mine Porphyry, which is 800 m by 2000 m in plan view.

On the basis of examination of a limited number of thin sections, it would appear that: (1) the second generation of plagioclase phenocrysts is more abundant; (2) the matrix is more sericitic; (3) the larger first generation plagioclase phenocrysts are commonly fractured and the cracks filled with sericitic material; and (4) chlorite appears as a constituent of the matrix (about 1 percent) as the South Bay orebody is approached. These patterns suggest that the changes are a mineralogical expression of the ore-forming event (Sopuck 1977).

The flows of formation M are generally separated from the Mine Porphyry by the dacite breccia of Pollock *et al.* (1972) which has been interpreted here (formation M) as a dome-collapse breccia. The Mine Porphyry has a foliation at variance with the regional tectonic foliation which is parallel to the margins of the intrusion. Fragments of the Mine Porphyry a few centimetres in size, set in a matrix of the same material, termed ghost breccia (J. Wan, Selco Incorporated, personal communication, 1974), may represent the fragmental carapace of a volcanic dome (cf. Macdonald 1972).

On the basis of the above points, Pollock *et al.* (1972, p.303) and Asbury (1975, p.7, 8) conclude that the Mine Porphyry is an endogenous dome. The sills within the map-area appear to be either minor offshoots of the main dome, or, as with the Lost Bay sill, differentiates of the granophyric granodiorite, given their close spatial association and similar petrography. This would tend to support a close temporal relationship between the granodioritic rocks and the rhyolite porphyry.

Numerous narrow (3 cm to 10 m) dikes of massive white to buff weathering rhyolitic quartz porphyry occur within formation H. They consist of 10 to 20 percent albite or quartz and feldspar phenocrysts, 1 to 2 mm, generally subhedral to euhedral set in an aphanitic groundmass. These dikes cut all unmetamorphosed granitic rocks, but they tend to be concentrated in the eastern two thirds of Earngey Township. They generally have a chilled margin from 2 mm to 2 cm thick and rarely exhibit mineral foliations parallel to their margins. This is evident in particular on an outcrop of reworked felsic pyroclastic rocks at the southeastern part of Lost Bay, where the alignment of chlorite grains in a crosscutting dike define a foliation. In some places the dikes have been contaminated with 5 to 10 percent of 0.5 to 1 mm rounded to angular xenoliths of the surrounding rock types.

The groundmass of the dikes consists of 0.01 to 0.02 mm rounded anhedral, grains of quartz and feldspar which form a hypidiomorphic-granular texture. The proportion of quartz to feldspar is generally 1:4. Scattered, 0.1 to 2 mm, grains of subhedral biotite and subordinate muscovite occur throughout the groundmass forming 5 to 10 percent of the rock accompanied by trace amounts of sphene, opaque iron-titanium oxides, and epidote. The phenocryst population is variable with 3 to 5 percent quartz phenocrysts in the rhyolitic porphyries, whereas the feldspar porphyries contain phenocrysts of orthoclase and plagioclase of similar size. Both feldspars are commonly slightly saussuritized, and generally the plagioclase is An_{20-30} in the unaltered cores of phenocrysts which form a maximum of 10 percent of the rock. Compositionally these rocks are biotite microquartz monzonite and their mineral assemblages are indicative of greenschist facies metamorphism.

One dike on the east shore of Leg Lake is a biotite microgranophyric quartz monzonite, although it was mapped in the field as an aphanitic felsite. The dike consists of 50 percent granophyric oligoclase laths 0.6 by 0.2 mm and 20 percent subhedral equant potassic feldspar grains, 20 percent anhedral 0.3 mm grains of quartz, 5 percent subhedral grains of muscovite, 1 to 2 percent epidote, and accessory sphene, carbonate, chlorite, and pyrite.

UNMETAMORPHOSED FELSIC TO INTERMEDIATE INTRUSIONS

There are four major bodies of unmetamorphosed granitic rock in the general area; the Okanse Batholith centred on Okanse Lake, the Perrigo Batholith centred on Perrigo Lake, the Costello Lake Stock west of Costello Lake outside the map area, and the Allison Lake Batholith outside the map area. These batholiths are relatively simple, consisting of two or three phases, in distinct contrast to those found elsewhere in the Shield (Ziehlke 1975; Ayres 1974). Mapping of the granitic terrain is not however as detailed as that of the remainder of the area, and the conclusion regarding their complexity is tentative. The various phases are mappable on the basis of composition, abundance and character of ferromagnesian minerals, and presence and character of phenocrysts.

PHYSICAL VOLCANOLOGY

Cyclical Volcanism

A cycle is defined as: "A series of events or changes that are normally, but not inevitably, considered to be recurrent and to return to a starting point, that are repeated in the same order several or many times at more or less regular intervals, and that operate under conditions which at the end of the series are the same as they were at the beginning" (AGI 1972, p.176). Cyclical volcanism is the repetition of volcanic stratigraphy, and in an Archean context, this has generally referred to the repetition of mafic to felsic sequences of rocks (Goodwin 1967, 1968).

Anhaeusser (1971) examined cyclicity in Archean volcanic rocks and described its occurrence on four scales.

1. Mini-cycles: measured in centimetres or parts thereof e.g. greywacke-argillite couplets or felsic tuff-chert couplets.
2. Minor-cycles: measured in metres, tens of metres, hundreds of metres, for example parts of Cycle II where basaltic andesite to rhyolite cycles take place over about 150 m intervals.
3. Major-cycles: "a few hundred to many thousand of metres' thick, for example the cyclical volcanism of Ayres (1977). Cyclicity on this scale occurs in the Norseman area of western Australia (Doepel 1965; quoted by Glikson 1976) and in the Bulawayan Group of Rhodesia (Bliss and Stidolph 1969).
4. Super-cycles: include the whole of a volcanic-sedimentary pile and may change from ultramafic to tholeiitic to calc-alkalic to alkalic and include thousands of metres of stratigraphy.

In the Abitibi metavolcanic-metasedimentary belt of the Canadian Shield, D.R. Pyke (1978a) and L.S. Jensen (1979) have described the threefold recurrence of a volcanic super-cycle involving basaltic komatiite succeeded in time by high-Fe and high-Mg tholeiitic basalt through tholeiitic rhyolite to calc-alkalic basalt through rhyolite. Archean volcanic cycles of this magnitude appear to be unusual in their stratigraphic thickness and chemical variety. A fur-

TABLE 13 STYLES OF ARCHEAN CYCLICAL VOLCANISM

Area	Units Represented (after Wilson *et al.* 1974 and Jensen 1979)	Scale of cyclicity (after Anhaeusser 1971)	Reference
S. Africa (Onverwaacht Grp.)	Lower basic middle basic	Super-, major-cycles	Anhaeusser 1971
Rhodesia (Bulawayan)	Lower basic, middle basic, upper cyclic	Super-, major-, minor-, mini-cycles	Bliss & Stidolph 1969
W. Australia (Kalgoorlie)	Lower basic, middle basic, middle felsic	Super-, major-, minor-, mini-cycles	
(Norseman)	Lower basic, middle basic, middle felsic	Major-, minor-, mini-cycles	Doepel 1965
Canada (Gods Lake Subprovince)	Upper cyclic	Major-, minor-, mini-cycles	Hubregtse 1976; Ayres 1977
(Wabigoon Subprovince)	Lower basic, middle basic, middle felsic, upper cyclic, alkalic	Super-, minor-, mini-cycles	Blackburn and Trowell 1978
(Abitibi Subprovince)	Lower basic, middle basic, middle felsic, upper cyclic, alkalic	Super-, minor-, mini-cycles	Pyke 1978a; Jensen 1978a,b; 1976
(Uchi Subprovince)	Lower basic, middle basic, middle felsic	Super-, major-, minor-, mini-cycles	this work; H. Wallace, Ontario Geological Survey, 1978, personal communication

ther compilation of examples of the various scales of volcanic cyclicity is listed in Table 13.

Speculation as to the causes of super-cycles versus major-cycles involves consideration of the following observations with respect to super-cycles.

1. A komatiite through calc-alkalic rhyolite super-cycle involves production of komatiitic liquids by 30 to 50 percent melting of mantle source (Arndt 1977) with no clear evolutionary path between the komatiitic and the overlying tholeiitic suites which are produced by lesser degrees of partial melting (Condie 1976). Both suites have distinct intermediate differentiates (Arndt 1977).
2. Super-cycles of the Abitibi Subprovince appear to have evolved in a relatively short space of time (Nunes *et al.* 1978) late in the Archean
3. Super-cycles appear on the basis of limited data (Pyke 1978b; Jensen 1978a, 1979; Dimroth and Rocheleau 1979) to be the product of mafic volcanism erupting from regionally extensive fractures followed by siliceous volcanism from areally restricted centres. In major-cycles the felsic volcanism is on about the same scale as the mafic volcanism, both emanating from areally restricted volcanic centres (Ayres 1977; Thurston *et al.* 1978).

Wilson *et al.* (1974), based upon Canadian and Australian examples, postulated a fourfold division of Archean volcanic succession as follows:

Unit Name	Main Rock Types	Intrusive Rocks
Upper Cyclic	Basalt through rhyolite	Small ultramafic plugs
Middle Felsic	Intermediate pyroclastic rocks	Layered gabbro-pyroxene-peridotite
Middle Basic	Tholeiitic basalt, minor intermediate pyroclastic rocks	Large gabbro sills
Lower Basic	Mg basalt, no amygdules	Large ultramafic sills

This scheme does not appear to adequately represent the extent of ultramafic volcanism found in the South African Shield (Viljoen and Viljoen 1969; Anhaeusser *et al.* 1969).

Cyclicity in the Confederation Lake Area

Cyclicity in the lithologies in the Confederation Lake area is on the scale of Anhaeusser's (1971) major-cycles. Cyclicity on the minor-cycle scale occurs in Cycle II on the east limb of the regional synclinorium where cycles ranging from basaltic andesite to rhyolite occur over a stratigraphic interval of about 900 m.

Anhaeusser's (1971) type of mini-cycles are of course observed in thin-bedded rhyolitic tuff with cherty tops 5 to 10 mm thick, and in the form of wacke-argillite couplets, particularly in member B_2. Mini-cycle scale cyclicity is present in numerous tuff beds with quartz-rich tops within Cycle II, and in virtually all the bedded volcanic and sedimentary units such as the HST (Hill-Sloan-Tivey) chert.

The three major-cycles are defined by progression from a mafic base through to a felsic top. Cyclicity in a minor-cycle scale is present as:

1. discrete Fe-enrichment cycles ranging from basalt to andesite in formations A, E, and K, in respectively Cycles I, II, and III (Thurston and Fryer, in press),
2. four cycles in formation F ranging from basaltic andesite flows through to rhyolite tuff,
3. the upper part of formation H on the east limb where fining upward subaqueous ash flows are repeated seven times,
4. formation H on the west limb, where two ignimbrite flow units are found (Thurston 1979) representing repeated subaerial eruption,
5. the sequence of thick felsic flows in formation M occurring associated with the dome of Cycle III.

Facies Variation and Paleovolcanic Reconstruction

Stratigraphic units have been defined on the basis of composition; facies variation is defined by texture, primary structure and structure sequence reflecting mechanism of extrusion or emplacement. Facies in mafic flows are based upon vesicularity, volcanic structure such as pillows, breccia, and layered hyaloclastite units or unbedded hyaloclastite, and thickness variations of the mafic unit as a whole. The presence of accidental fragments, the degree of alteration, and the type of sedimentary structures in the hyaloclastites also serve to define facies. In intermediate flows, facies analysis is based upon volcanic structures and relationship to mafic flows. In an example from the Abitibi Belt, E. Dimroth and M. Rocheleau (1979) observed that as intermediate flows are more viscous than basalt, they tend to be concentrated near the volcanic centre relative to less viscous, more widespread basalt.

In felsic flows, facies are defined by volcanic structures such as ribboning (Dimroth and Rocheleau 1979), brecciation, and position with respect to subvolcanic domes. In pyroclastic rocks, facies are defined by grain size, texture of fragments and matrix, and sedimentary texture and structure.

Pyroclastic eruptions have been classified by G.P.L. Walker (1973) using two parameters:

1. the dispersal index (**D**) i.e. the area enclosed by the 0.1 Tmax isopach where Tmax is the maximum thickness at source, and
2. the fragmentation index (**F**) which is the weight percent of particles finer than 1 mm at 0.1 Tmax.

Using these parameters Walker subdivides pyroclastic deposits into four types:

1. Strombolian (small **F** and **D** < 5 km^2)
2. Sub-Plinian (small **F** and **D** < 100 km^2)
3. Plinian (larger **F** than sub-Plinian **D** > 500 km^2)
4. Surtseyan (large **F**)

Sparks *et al.* (1973), Sparks and Wilson (1976), and Wilson (1976) describe the characteristics of the Plinian eruption-type in terms of a larger **F** than the Strombolian and sub-Plinian types and a larger **D**.

Mechanical analyses of consolidated Archean metavolcanics and estimates of dispersal of products of single eruptions in Archean terrain are difficult to make and of uncertain reliability, but it is still possible to roughly classify the pyroclastic rocks of the Confederation Lake area. Ash flows are generally considered to be the result of the gravitational collapse of a gas-charged Plinian eruption column (Sparks and Wilson 1976) containing lithic fragments and the products of vesiculating felsic magma-shards, pumice, and crystals (Sparks 1978).

Calderas are commonly associated with voluminous eruptions of ash and pumice. Therefore the following review of caldera associated volcanism is provided, summarized from Smith and Bailey (1968) and H. Williams (1941).

The term caldera is defined by Williams (1941, p.242) as "a large volcanic depression, more or less cirquelike in form". A part of Williams' classification of calderas with modifications by Smith and Bailey is as follows:

> Type 2 calderas are associated with differentiated volcanoes and are characterized by voluminous eruptions of pumice and ash. These have been termed Krakatoan by Williams.

Williams and McBirney (1979, p.207) have further subdivided Williams (1941) classification of calderas with the introduction of the Valles-type which represents "foundering . . . along arcuate fractures independent of pre-existing volcanoes as a consequence of and simultaneously with a discharge of colossal volumes of siliceous pumice..."

Seven stages of caldera activity are described by Smith and Bailey (1968) with respect to structural, volcanic, and plutonic events (Table 14).

Reconstruction of Facies in the Confederation Lake Area

In order to visualize facies and thickness relations within the Confederation Lake area a pre-folding reconstruction (Figure 12) has been made. The part of the volcano which extends out of the present map area and into the Birch Lake area to the north has been included in order to show the facies relations more clearly.

CYCLE I

Formation A is mainly pillowed, poorly vesiculated, and as a whole thickens to the north in the area of north Corless Township. However, the presence of minor amounts of andesitic flows south of the Bear Lake Fault in the upper part of formation A, and the southward thickening of formation B, all suggest a source area for Cycle I volcanism to the south in the area now occupied by granitic intrusions (see map, back pocket; see summary Table 15).

On the east limb of the regional synclinorium, Cycle I is exposed in the core of the Leg Lake anticlinorium (Figure 13) with pillowed mafic flows containing no hyaloclastic debris, and numerous massive and porphyritic flows with pillowed tops, minor hyaloclastite at the top (Dimroth 1975, flow type f), and in-

TABLE 14 | GEOLOGIC EVENTS OF THE RESURGENT-CAULDRON CYCLE (after Smith and Bailey 1968)

Stage	Structural Events	Volcanic Events	Sedimentary Events	Plutonic Events	Duration in the Valles Caldera
I	Regional tumescence and propagation of ring and radial fractures with possible apical graben subsidence.	Eruptions due to leakage along radial or ring fractures.	Erosion of the volcanic highland.	Compositional zonation in magma chambers. Increasing magma pressure. Minor intrusion.	$< 4 \times 10^5$ yrs.
II	—	Major ash flow eruption. 50-500 $mi.^3$	—	Degassing and skimming of zoned top of chamber.	< 10 yrs. est.
III	Caldera collapse.	Overlap with Stage II in some calderas.	Avalanches and slides from caldera walls.	Disequilibrium.	< 10 yrs. est.
IV	—	Minor pyroclastic eruptions and lavas on caldera floor in some calderas.	Caldera fill; talus, avalanches, slides, fans, lake deposits.	Consolidation of magma caught in ring fractures residual ring dikes. Progressive recovery of equilibrium. Beginning of minor ring intrusion.	
V	Resurgent doming.	Possible ring-fracture volcanism and/or eruption or intrusion in dome fractures.	Caldera fill continues. Lake overflows and caldera is breached.	Rise of central pluton and perhaps a ring-intrusion stage.	$< 10^5$ yrs.
VI	Possible regional tumescence and re-opening of ring fractures.	Ring-fracture volcanism. Possible Stage II eruption of next cycle.	Caldera fill continues, late lake sediment. Erosion of fill. Fill > erosion.	Final emplacement and differentiation of ring intrusions. Possible stoping by central pluton.	8×10^5 yrs. $\pm 10^5$ yrs.
VII	—	Terminal fumarolic and hot spring activity. (hydrothermal alteration)	Erosion. Erosion > fill.	Crystallization of major plutons. Possibly a major ore-forming stage.	$> 10^5$ yrs.

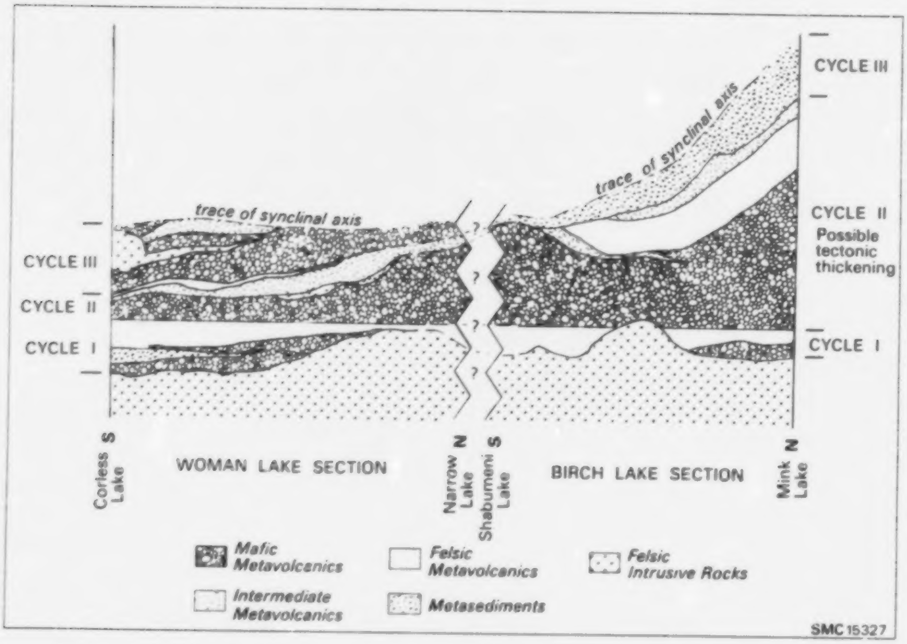

CYCLE III
CYCLE II
CYCLE I
trace of synclinal axis
trace of synclinal axis
CYCLE III
CYCLE II
Possible tectonic thickening
CYCLE I
?
?
?
?
?
S
Corless Lake
WOMAN LAKE SECTION
N
Narrow Lake
S
Shabumeni Lake
BIRCH LAKE SECTION
N
Mink Lake
Mafic Metavolcanics
Intermediate Metavolcanics
Felsic Metavolcanics
Metasediments
Felsic Intrusive Rocks
SMC 15327

Figure 12–Reconstructed prefolding cross-section showing relationship of Cycles. (Birch Lake section largely diagrammatic lies to the north outside the map area).

TABLE 15 SUMMARY OF STRATIGRAPHY AND EVOLUTION OF CYCLE I IN THE UCHI-CONFEDERATION LAKES AREA.

FORMATION	THICKNESS (metres)	DOMINANT ROCK TYPE	MINOR ROCK TYPE	FACIES ANALYSIS AND DEPOSITIONAL ENVIRONMENT	ENVIRONMENTAL INDICATORS
A west limb of fold	966-2494	Mafic flows, massive flows, amphibole phyric flows	Pillowed mafic flows intermediate tuff & lapilli-tuff, feldspar phyric mafic flows	Subaqueous flows. Unit thins to S. Lower part of unit removed by granitic intrusions.	Pillowed, scarce and small amygdules.
B west limb of fold	0-1487	Wacke, argillite	Felsic tuff	Slightly coarser to the S. On the east limb, coarsens south to the conglomeratic facies of the English River Subprovince.	Thick- to thin-bedded on east limb, thin-bedded on west limb.
C west limb of fold	305-322	Felsic lapilli-tuff	Felsic tuff	Minor thickness and lateral extent (2 km.) due to incomplete preservation. Suggestive of ash flow eruption in shallow subaqueous or subaerial environment. Proximal equivalent of metasediments listed above.	Spherulites, flattened fiamme, abundant relict flattened shards.
B both limbs of fold	925-2776	Intermediate lapilli-tuff	Felsic tuff	Coarsens to the south and east. Varies from unbedded pumiceous tuff-breccia to parallel laminated tuffs fining upward and northward. Great lateral extent vs thickness (16 km vs 1800 km) suggests downslope movement of breccia. Monolithic close to source, heterolithic downslope. Transition from vent facies in S. to distal facies in N. marked by increase in rounding & proportion of pumice, number of exotic fragments, and decrease in bedding thickness.	Abundant pumice, heterolithic, fining upward thick-bedded to massive in proximal environment.
D west limb of fold Narrow Lake	0-61	Marble	Chert & pyrite	Subaqueous, shelf environment?	Thin-bedded, fine-grained, no stromatolites, sulphide-rich beds therefore subaqueous, fumarolic relatively proximal.

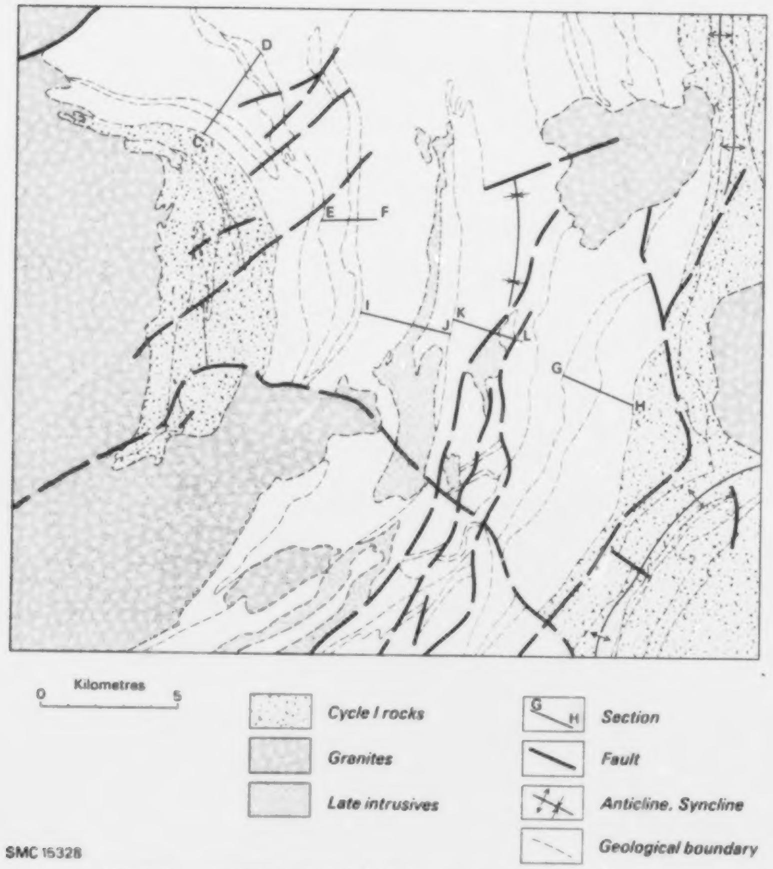

D
C
E
F
I
J
K
L
G
H
Kilometres
0
5
Cycle I rocks
Granites
Late intrusives
Section
Fault
Anticline, Syncline
Geological boundary
SMC 15328

Figure 13–General geology of Cycle I, contacts after Figure 3.

terbeds of finely laminated intermediate and felsic tuff. The presence of tuff interbeds between relatively thin flows on the east limb only, and lack of hyaloclastic debris suggests that the east limb is more distant from a source than the west limb because hyaloclastic debris is usually relatively close to the volcano (cf. Dimroth *et al.* 1978). In contrast, the lack of tuff interbeds in formation A on the west limb and greater thickness of formation A there suggests that the west limb is more proximal.

Within formation B on the west limb, thin-bedded crystal lithic air-fall tuffs of intermediate composition which are assumed to be relatively distal, occur interbedded with coarse conglomeratic pumiceous ash flow deposits, assumed to be relatively proximal based on thickness of the unit on this limb relative to the east limb. This intermixing of styles and products of eruption and proximal and distal facies implies more than one source area. Most units are only a few tens of metres thick, therefore the source area is relatively distant.

The lack of welding, and abundant pumice, suggest a relatively shallow subaqueous environment for the air-fall eruptions. The depositional environment must have been relatively deep water given the interfingering of abyssal wackes and pyroclastic rocks.

Eruption Type and Environment of Deposition

The following observations with respect to Cycle I bear on the eruption type and environment of deposition.

Formation A is characterized by:

1. lack of vesiculation in the basalt flows
2. large pillows
3. lack of abundant hyaloclastic debris
4. widespread distribution and limited thickness of the unit

Pyroclastic units of formations B and C feature:

1. conglomeratic intermediate ash flow units with abundant pumice
2. thin-bedded fine-grained rhyolitic tuff
3. mafic flows and abundant dikes

Based upon the reconstructed shape of the volcano (see Figure 12) and the lack of alternating flow-pyroclastic sequences, the mafic flows represent quiet effusions from a shield volcano. Conventionally, vesicularity is taken to indicate a relatively shallow depth of submarine extrusion (Jones 1969). However, data from Project Famous (Bryan and Moore 1977) indicate that vesicularity in basaltic rocks is also a function of the content of K_2O and SiO_2. Therefore, although the Cycle I mafic flows are not very vesiculated, a relatively shallow water depth for the volcano (less than 500 m) is postulated based on the presence of the overlying pyroclastic rocks (cf. McBirney 1963; McBirney and Murase 1971; Sparks 1978).

Large-Scale Reconstruction

The ash flow deposits south of Narrow Lake may represent continued eruption from an edifice with many subsidiary vents. This is based upon the rather uniform thickness and great lateral extent of formation B.

Preserved evidence of stratovolcanoes in Archean terrains usually consists of a thick proximal mafic section with interdigitated pyroclastic rocks. Thickening of the mafic flow accumulation with pyroclastic units is not as apparent in shield volcanoes. The lack of evidence for a thick central edifice, that is a stratovolcano, could be due to erosion of the thicker section, or it may not be present in the exposed section. Pyroclastic activity from a shield volcano during the early stages of volcanic activity is known from the Valles caldera (Smith and Bailey 1968) where relatively widespread ash flows are related to an early tumescent stage (see Table 13).

Depth below water of eruption of member B_1 must have been less than 500 m which is the maximum depth for explosive activity (cf. McBirney 1963; McBirney and Murase 1971; Sparks 1978).

CYCLE II

Reconstruction of Facies

On the west limb of the regional synclinorium formation E consists of pillowed basaltic (Thurston and Fryer, in press) flows with intercalated andesite, both of which are moderately vesicular (25 to 30 percent). There are many gabbroic sills intercalated with the flows. Cycle II as a whole is thickest at Narrow Lake. On the east limb of the fold formation E is also pillowed, but andesitic rocks are less abundant (Johns 1976) and vesicularity is in the range of only 10 to 15 percent (Figure 14, Table 16).

Above formation E is a thick accumulation of intermediate subaqueous to subaerial pyroclastic flows of formation G. On the west limb, tuff-breccia and lapilli-tuff composed of pumiceous essential fragments form beds about 3 m thick overlain by 5 to 10 cm thick beds of massive tuff. Coarse beds appear to fine upward. Several occurrences of sandy pumice-tuff and pumice-tuff (Yamada 1973) are on the west limb, generally fining upward into thin-bedded intermediate tuff. On the east limb, the subaqueous ash flow model of Yamada (1973) is more fully developed . There are seven fining upwards units 150 to 300 m thick which also fine southward away from an assumed volcanic centre. Pumice and shards formed during this phase of activity are rounded to angular without re-entrant angles, perlites, or in situ brecciation. These rocks appear to be the product of magmatic explosive activity (cf. Dimroth 1977; Sparks 1978).

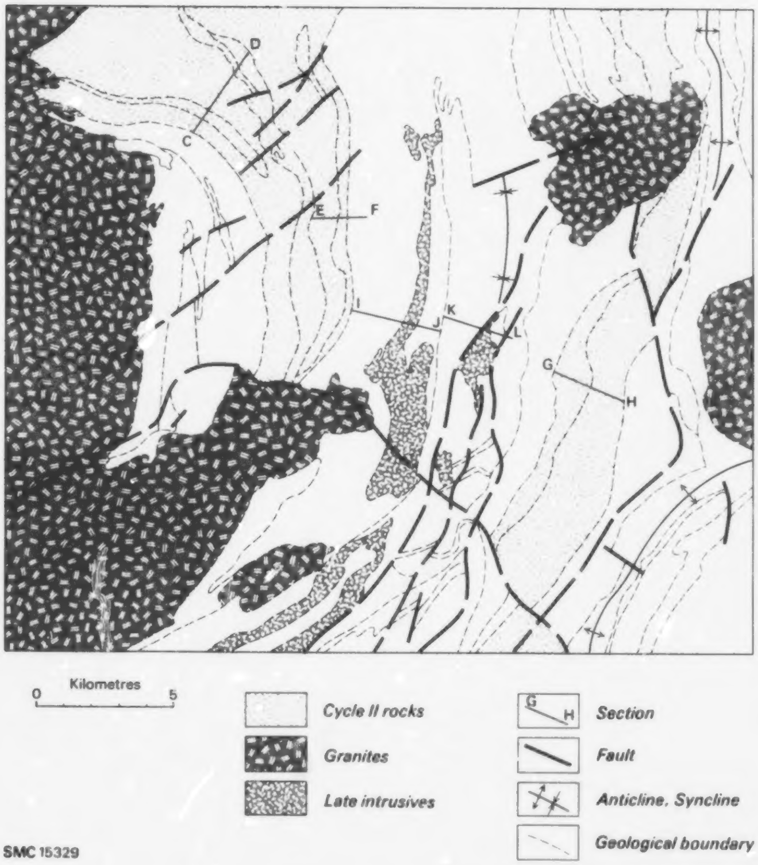
The presence of pumiceous tuff-breccia overlain by finely laminated tuff in the Narrow Lake area is analogous to a telescoped A-E turbidite sequence (Bouma 1962). This is indicative of a relatively proximal environment (cf. Fisher 1979). Conversely the gradually fining upward nature of the subaqueous ash flows of the east limb represent a more distal environment (cf. Yamada 1973; Fisher 1979).

Formation F on the east limb is intercalated with and overlies formation E, and consists of thin (10 m) pillowed mafic to intermediate flows containing 20 to 30 percent vesicles and abundant interpillow chert. These flows are separated by 1 mm to 1 m thick beds of air-fall felsic tuff. The tuff is well sorted with a few lithic fragments about 2 mm giving way upward to exclusively ash-size particles at the top of each fining upward bed.

An intensely welded rhyolitic ignimbrite overlies the intermediate to felsic subaqueous ignimbrites on the west limb (Savory 1976; Thurston 1979).

A volcanic centre is postulated to have existed in the area of Narrow Lake based upon the increased thickness of formation E in that area, the greater abundance of gabbro sills there, and the apparent restriction of andesite flows to the area of the volcanic centre (cf. Dimroth and Rocheleau 1979). The pattern of proximal subaqueous ash flows analogous to A-E turbidites of Narrow Lake succeeded to the south by what can be interpreted as a more distal facies based upon Yamada's (1973) model also supports the existence of a centre in that area.

The minor-cycles on the east limb, given the chemical dissimilarity to Cycle II basalts (Thurston and Fryer, in press) and the thin-bedded, fine-grained


D
C
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Kilometres
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5
Cycle II rocks
Granites
Late intrusives
G H
Section
Fault
Anticline, Syncline
Geological boundary
SMC 15329

Figure 14–General geology of Cycle II, contacts after Figure 3.

character of the tuffs, represent a possible satellitic source, or different conditions of transport or volcanism at the same source.

Eruption Type and Environment of Deposition

Abundant pillows in the basalts of Cycle II affirm the subaqueous nature of its lower part. Water depth would have been relatively shallow, based upon the presence of 20 to 30 percent vesicles in the pillows (cf. Jones 1969). The overlying intermediate pyroclastic rocks suggest a water depth of less than 500 m. (cf. McBirney 1963; McBirney and Murase 1971; Sparks 1978). They are also suggestive of a relatively proximal shallow water environment solely by analogy with other subaqueous ash flows (Yamada 1973; Fiske 1963).

TABLE 16 SUMMARY OF STRATIGRAPHY AND EVOLUTION OF CYCLE II IN THE UCHI-CONFEDERATION LAKES AREA.

FORMATION	THICKNESS (metres)	DOMINANT ROCK TYPE	MINOR ROCK TYPE	FACIES ANALYSIS AND DEPOSITIONAL ENVIRONMENT	ENVIRONMENTAL INDICATORS
E west limb of fold	2100-3623	Mafic flows, intermediate flows, mainly pillowed	Intermediate and felsic tuff, cherty interflow units, oxide facies iron formation	Subaqueous flows. Unit thins to S. and E. overlies exhalative units of Cycle I, represents migration northward of volcanic centre, fumarolic epidotization more intense where interflow metasediments more prominent in section. Proximal: varioles more common, amygdules more abundant. Interflow metasediments common. Distal: Fewer andesitic units interflow metasediments, varioles, smaller pillows, fewer amygdules.	Pillows, amygdules, varioles, andesitic flows.
G proximal facies west limb of fold	0-1106	Intermediate lapilli-tuff, tuff	Argillite, chert, wacke	Grades to south into finer more thinly bedded distal facies. Intermediate in position between distal and vent facies-transported.	Thin-bedded, rounded pumiceous clasts, argillite interbeds.
G distal facies Confederation Lake	483-2816	Intermediate lapilli-tuff	Tuff-breccia & tuff	Proximal (vent) facies: subaqueous pumice flows, rare interbedded pillowed flows, all on the flanks of a stratovolcano.	Tuff-breccia units reverse and normally graded fining upwards into thin-bedded tuff, abundant pumice. Monolithic fragment population similar composition of coarse & fine fractions, presence of sulphide clasts.
H proximal facies Woman Lake	0-724	Felsic lapilli-tuff	Tuff, porphyritic flows	Subaerial intensely welded fining upwards ignimbrite sheets. To the N. & S. passes into unwelded units assumed to be subaqueous.	Eutaxitic texture, fiamme, intensely welded with replacement of fiamme by silica, snowflake texture.

TABLE 16 | **cont'd.**

FORMATION	THICKNESS (metres)	DOMINANT ROCK TYPE	MINOR ROCK TYPE	FACIES ANALYSIS AND DEPOSITIONAL ENVIRONMENT	ENVIRONMENTAL INDICATORS
H transported facies Lost Bay, Confederation Lake	640-1086	Felsic lapilli-tuff	Tuff, tuff-breccia	Transported subaqueous equivalent of the above unit. Subaqueous ash flows with normal and reverse graded units. Four fining upwards units present 30-150 m thick.	Pumiceous fining upward and distally reverse and normal grading, sulphide clasts.
J Woman Lake	91-152	Marble	Chert, oxide facies iron formation	Shallow submarine stromatolitic marble overlain by chert. Relatively proximal exhalative origin on west limb where marble occurs. Distal iron formation on east limb.	Stromatolites in carbonate.
F Lost Bay, Confederation Lake	122-183 each 975-1931 total	Mafic flow	Felsic tuff hyaloclastite	Proximal subaqueous flows thin to north and south of Lost Bay, product of satellite cone of main stratovolcano. Total of 7 units, each about 60 percent mafic flows, remainder intermediate to felsic pyroclastic rocks. Commonly strongly altered. Capped by 1-2 m exhalative units. Overlain by the transported felsic pyroclastic rocks.	Abundant hyaloclastic debris and pillowed flows. Beds of air-fall tuff & tuff-breccia. Exhalative units.

The welded ash flow capping Cycle II on the west limb has intensely welded shards, silica replacement of fiamme, and vapor phase recrystallization of K-feldspar to snowflake texture (cf. Torske 1975), which taken together are indicative of a subaerial deposition. Welding is, of course, possible in the subaqueous environment (Francis and Howells 1973), but the intensity of recrystallization of the pumiceous lapilli and the degree of welding of the shards suggest that the unit was definitely deposited subaerially (M. Howells, Institute of Geological Sciences, London, England, personal communication, 1977).

A stromatolitic carbonate overlies the welded rhyolite tuff indicative of deposition in the photic zone of a marine environment (Playford and Cockbain 1976). The available information suggests that maximum depth for growth of the organisms is 100 m in the clearest ocean water and 50 m in average ocean water (Brock 1976).

Cycle II volcanic activity commenced with quiet effusions of basaltic magma typically non-viscous relative to more siliceous compositions from a shield volcano. Later pyroclastic activity can be classified using Walker's (1973) parameters.

Coarse fragments, blocks, bombs, and lapilli make up a substantial part of the base of each ash flow therefore, qualitatively, **F** is relatively small. Dispersal is on the order of 500 km^2. Dispersal was calculated by assuming a depth of infolding of about 4 km derived from Thurston and Breaks (1978), and V.K. Gupta *et al.* (1982) and the lateral extent for Cycle II from Thurston (1977), assuming that volcanic rocks did not overlie adjacent areas presently underlain by granitic rocks. Therefore, it is concluded that the ash flows of the middle part of Cycle II in the vicinity of Narrow Lake on the west limb and Lost Bay on the east limb are the product of Plinian eruptive activity (cf. Sparks *et al.* 1973). The fine vitric crystal tuffs capping each of the minor-cycles in formation F are the product of Plinian air-fall activity relatively distal to the volcanic centre as they are fine grained, and finely bedded (cf. Fisher 1979).

Distribution of ash flows suggests that slopes were less than 10 degrees inasmuch as ash flows do not usually deposit upon steeper slopes, at least in the subaerial environment (Bond and Sparks 1976). The thinly laminated tuffs capping many of the coarse units of the ash flows were deposited from the turbulent dust cloud observed above many ash flows (Bond and Sparks 1976; Sparks *et al.* 1973; Fisher 1979).

In the model presented by Sparks *et al.* (1973) Plinian activity is commonly followed by an effusive nonexplosive phase. Scattered units mapped as quartz- and feldspar-phyric felsic flows on the shores of Woman Lake and several basaltic flows between Woman and Narrow Lakes are the products of this effusive phase of activity.

The welded ash flows forming the upper part of Cycle II on the west limb (Savory 1976; Thurston 1978) have prominent reverse grading of pumiceous clasts, great lateral extent, and a high degree of fragmentation (F = 50). Therefore they may represent the renewal of sub-Plinian activity (cf. Sparks *et al.* 1973).

Large-Scale Reconstruction

The alternating massive and pillowed flows around Narrow Lake form a marked thickening of the volcanic section possibly representing the basaltic part of a shield volcano. The intermediate to felsic part of Cycle II represents large volumes of predominantly ash and pumice, suggestive of the early stages (see Table 13) of caldera activity.

The overall sequence of lithologies in formation G of Cycle II, the presence of pumice blocks in unwelded ignimbrites, the size gradation of fragments both laterally and vertically, and the presence of reverse grading, all suggest that the Plinian phase (Sparks *et al.* 1973) was of the Krakatoan type (Williams 1941). In this type of caldera, the collapse of the volcanic edifice is the result of the collapse of the roof of the magma chamber. This collapse is a relatively final event, with no resurgence involving caldera filling, doming etc. such as described by Smith and Bailey (1968) for the Valles type caldera of the resurgent type. No preserved caldera-fill sequences have been found in the area examined.

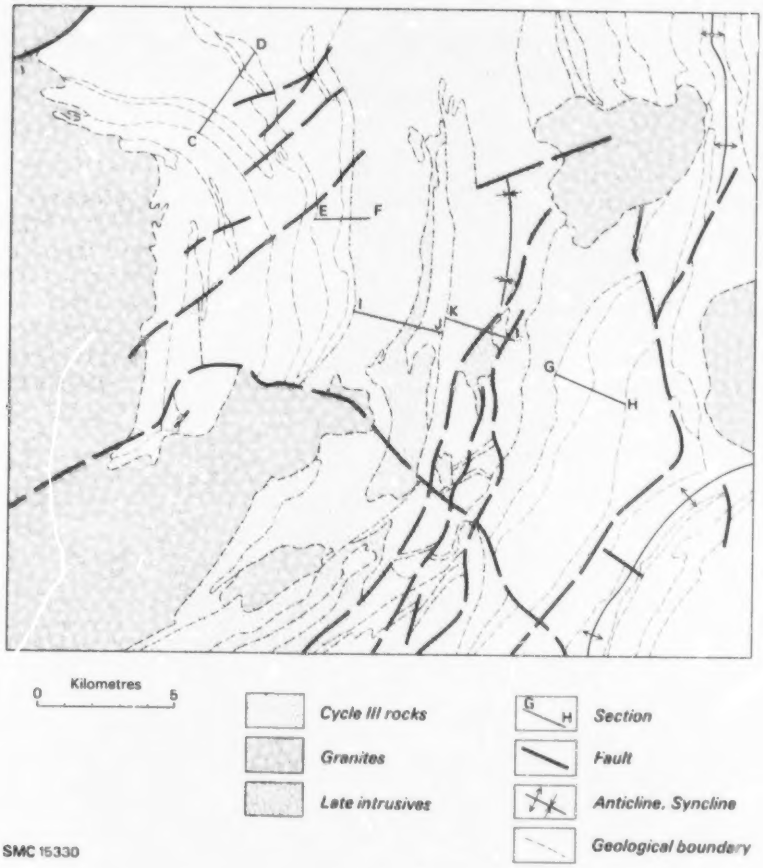
CYCLE III

Reconstruction of Facies

Formation K consists predominantly of pillowed flows with local lenses of broken pillow breccia, and layered and massive hyaloclastite tuff. The lack of massive flows is an indication of relatively rapid rates of extrusion or relatively distal facies (Dewitt and Stern 1978; An opposing view is offered by Lonsdale 1977). Thickening of the unit northward on both limbs of the fold suggests that the eruptive centre lies between Swain Lake, north of the map area, and Confederation Lake. The greatest thickness of intermediate to felsic pyroclastic rocks is in the vicinity of Mukukee Lake (Figure 15, map, back pocket). In addition, a substantial part of the section in the map area is composed of tuff-breccia containing epidotized rounded to angular pumiceous bombs in a spherulitic ashy matrix, which suggests proximity to an eruptive centre and retention of heat necessary to form spherulites (cf. Lofgren 1971a, b).

The fault-bounded block in which most of the products of Cycle III felsic volcanism are found is best termed a volcanic sector graben after Williams (1941 p.243). This is based upon the fault-bounded nature of the block (map, back pocket), the different structural trends within it, and the contrast between fold patterns and lineations within the feature (Asbury 1975) and those outside the block. A synvolcanic age for the block is suggested by the fact that most units of formation M are restricted to it. The structural pattern within the block requires first subsidence on the boundary faults, followed by volcanism confining most formation M units to the block, then regional folding

To the south of the map area, but within the fault-bounded sector graben in the area of Fredart Lake, the presence of several domical bodies of quartz-felds-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Cycle III rocks
Granites
Late intrusives
G H
Section
Fault
Anticline, Syncline
Geological boundary
SMC 15330

Figure 15–General geology of Cycle III, contacts after Figure 3.

par porphyry which grade into welded lapilli-tuff and felsic flows are suggested by Colvine (A.C. Colvine, Ontario Geological Survey, personal communication, 1979) to represent several local centres of felsic volcanism along the sector graben. Within the sector graben in the map area, formation M is characterized by coarse and pumice-rich pyroclastic ejecta, lack of bedding, and the presence of fragments with re-entrant angles (cf. Dimroth 1977). These points suggest magmatic explosive activity and local dome collapse as the origin for that formation (cf. Parsons 1969). The higher proportion of flows to pyroclastic rocks also suggests proximity to a volcanic centre.

Eruption Type and Environment of Deposition

Vesicularity of the pillowed mafic flows of formation K approaches 20 percent. Vesicularity alone would indicate water depth to be only a few hundred metres but the presence of zonation of vesicularity within individual pillows indicates a depth of approximately 350 m (cf. Jones 1969).

Formation L is poorly welded. Given that formation K pillow lavas are clearly submarine and the magmatic explosion origin of the overlying felsic pyroclastic rocks, a shallow submarine origin is proposed for formation K in spite of the observed eutaxitic textures (Table 17), inasmuch as no greater development of welding or recrystallization is found, and submarine welding is possible (cf. Francis and Howells 1973).

This eruptive event was succeeded by the foundering of the sector graben. Later eruptive activity within the graben included the development of a group of subvolcanic endogenous domes including the one below the South Bay Mine orebody at Confederation Lake (Pollock *et al.* 1972) and several to the south (A.C. Colvine, Ontario Geological Survey, personal communication, 1979).

Local magmatic explosions resulted in the production of breccia units of restricted lateral extent and more extensive rhyolitic flows within formation M.

Cycle III felsic volcanism involved resurgence of volcanism as Plinian or sub-Plinian eruptions. It is thus more closely allied to the resurgent type caldera exemplified by the Valles caldera (Smith and Bailey 1968), rather than the Krakatoan type.

Following Smith and Bailey's (1968) analysis of stage-by-stage development of resurgent cauldrons analogies can be drawn as shown in Table 18.

Time Constraints on Volcanism

Data on the periodicity of volcanism in general, and cyclical volcanism in particular, are scarce. Smith and Bailey (1968) have reviewed the chronology of volcanic events during the various stages of the caldera cycle model they proposed, indicating as shown in Table 14 that the whole cycle from Stage I to VII took less than 1.4×10^6 years. Smith (1979) reviewed the problem of periodicity in detail using data from many major ash flow eruptions. In his model, a large high-level magma chamber gradually differentiates, developing a high Si, volatile-rich most fractionated upper part, a "dominant volume" of relatively homogenous composition, and a lower part in which the silicic magma is mixed with underlying more primitive (perhaps basaltic) magma which provides, by repeated injection, a continuing source of heat for the system. Ash flow eruptions display pronounced chemical and mineralogical zonation (Hildreth 1979) with small volume systems erupting fragments of the underlying mafic magma (Sparks *et al.* 1977). The volume of erupted ash flows provided Smith with a

TABLE 17 | SUMMARY OF STRATIGRAPHY AND EVOLUTION OF CYCLE III IN THE UCHI-CONFEDERATION LAKES AREA.

FORMATION	THICKNESS (metres)	DOMINANT ROCK TYPE	MINOR ROCK TYPE	FACIES ANALYSIS AND DEPOSITIONAL ENVIRONMENT	ENVIRONMENTAL INDICATORS
K Confederation Lake	1030-1667	Mafic to intermediate pillowed flow	Hyaloclastic debris, massive & variolitic flows interflow metasediment	Proximal facies subaqueous flows. Thickest section at Washagomis Lake. Thins to S. Overlies shield volcano of Cycle II, separated by exhalative carbonate from Cycle II. Shield volcano.	Amygdules, hyaloclastite units, pillows, variolites, with spherulitic crystallization features, fumarolic alteration.
L Mukukee Lake	724-2574	Intermediate tuff & lapilli-tuff	Intermediate flows, tuff-breccia	Proximal shallow water subaqueous unit. Proximal aspect indicated by presence of flows, dikes, coarseness of fragments, thick bedding in coarse pyroclastic rocks. Presence of spherulites and textures indicating partial welding suggest minimal transport. Lack of textures of intense welding suggest subaqueous welding rather than subaerial. Violent Plinian eruption brings about initial collapse of sector graben.	Relict glass, spherulites, fumarolic alteration of bombs, thick bedding, partial welding.
M (Sopuck 1977) Confederation L. between Lost Bay and North Bay	2200	Felsic lapilli-tuff & tuff-breccia	Felsic flows, tuff, intermediate flows	Proximal: vent breccias derived from phreatic explosive activity in a fault-bounded moat or sector graben. Result of resurgent caldera activity. Subaqueous environment.	Fragments with re-entrant angles, abundant pumice, spherulites, partial welding, volcanogenic massive sulphide bodies.
porphyry dome Confederation Lake	0-1828	Quartz-feldspar porphyry	Argillite overlies dome locally	Endogenous dome of rhyolitic composition.	Phenocryst free margins, flow-aligned marginal zone, grades into partially welded upper zone (Asbury 1975) presence of ghost breccia.

TABLE 18 THE SMITH-BAILEY RESURGENT CAULDRON CYCLE AND ITS APPLICATION TO CYCLE III OF THE UCHI-CONFEDERATION VOLCANIC ROCKS (Smith and Bailey 1968).

Stage	Structural Event	Volcanic Event (general case)	Volcanic Event Uchi-Confederation area
I	Regional tumescence and propagation of ring and radial fractures with possible apical graben subsidence	Eruptions due to leakage along fractures	Not recognized
II	—	Ash flow eruption	Cycle III intermediate-felsic pyroclastic rocks
III	Caldera collapse	Overlap with Stage II	Intrusion of granodiorite sills etc. along fractures
IV	—	Minor pyroclastic eruptions on caldera floor	Not recognized
V	Resurgent doming	Eruptions associated with domes	Breccia and flows associated with quartz-feldspar porphyry dome at South Bay
VI	Regional tumescence & re-opening of ring fractures	Ring-fracture volcanism	Ash flow material filling graben south of Confederation Lake
VII	—	Fumarolic and hot spring activity	Formation of South Bay Mine orebody

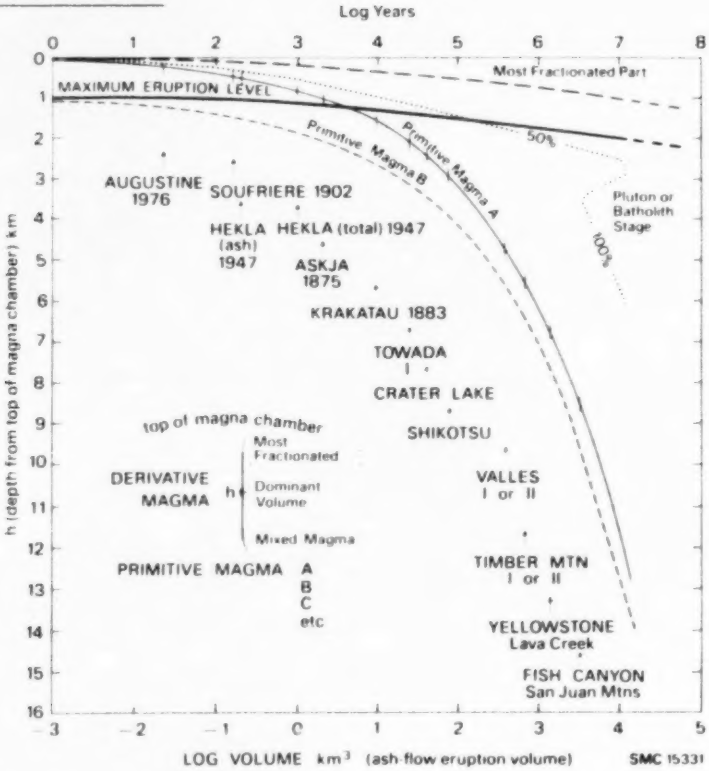

Figure 16–Relationship of volume of magma and volcanic periodicity after Smith (1979).

means of estimating the volume of the original magma chamber. The process of crystal fractionation as a differentiation mechanism takes time. W.I. Rose *et al.* (1979) estimated the amount of time required for phenocrysts to form and sink through a high-viscosity siliceous magma, given variable rock or viscosity, water content, and phenocryst size and growth rate. This permitted estimation of the total residence time in the upper crust for the Los Chocoyos ash flow magma chamber of in excess of 10^4 years. Smith's (1979) utilizing data of this sort and geochronologic control, suggested that periodicity is a direct function of magma chamber size (Figure 16).

CONFEDERATION LAKE AREA

In the Confederation Lake area a minimum volume estimate for Cycle II ash flow activity, both submarine and subaerial is approximately 2600 km^3 making no allowance for deformation, past or present porosity corrections, or erosion. The products of Cycle II magmatism are assumed to be confined to the map area and the Birch Lake area (Thurston 1977). The depth extent is about 4 km based on reasoning presented in Thurston and Breaks (1978) and Gupta *et al.* (1982) and the average thickness is derived from the map in the back pocket. Using Smith's (1979) approximations, the length of time represented by Cycle II felsic volcanism is on the order of between 10^6 and 10^7 years. U/Pb age determination on zircons from Cycles I, II, and III rhyolites (Nunes and Thurston 1980) gives a time interval of about 167 Ma for accumulation of Cycle II and 55 Ma for accumulation of Cycle III volcanic rocks. In estimating the volume of magmatism of each cycle, it was assumed that the eruptive products spread no farther than the two limbs of the major fold. Therefore much greater volumes undoubtedly existed. Using Smith's (1979) approximations it is possible that Cycle II felsic magmatism represents production from a large magma chamber over a protracted time period. Cycle III involves an approximate minimum volume of 500 km^3 of felsic volcanic rocks which does not match as well with Smith's (1979) model, but the uncertainties of volume estimation are greater given the extension of Cycle III into unmapped terrane to the south and west.

J.N. Ludden (1977) estimates the production rate of Piton de la Fournaise from volume data and geochronology at 3.9 to 6.3 m^3/sec, a much more rapid rate of volcanism than suggested by the Smith (1979) model. W.E Elston *et al.* (1973) document the existence of three volcanic cycles ranging from andesite to rhyolite terminated by basaltic andesite which took place over a time interval of 18 m.y., again a rapid rate of volcanism.

Given the similarity of Archean and younger volcanic products, the processes by which they form must be basically similar. The existence of extremely fractionated rhyolites with high trace element abundances in Cycle III (Thurston and Fryer, in press) suggests that compositional gradients existed in Archean magma chambers analogous to those described by W. Hildreth (1979) for younger rocks. This implies the existence of felsic magma chambers over long periods of time in the Archean, suggesting that Smith's (1979) estimates may have some validity in an Archean context.

STRUCTURAL GEOLOGY

Foliation, Schistosity, and Cleavage

A prominent metamorphic foliation can be observed in most outcrops of the metavolcanic-metasedimentary belt. The foliation is produced by the subparallel orientation of platy and acicular minerals such as muscovite, biotite, amphibole, and feldspar and by flattening of fragments. The foliation is marked in the area of hornblende-hornfels contact metamorphism by extensive recrystallization. Foliation is rare in the intrusive mafic to ultramafic rocks of map unit 6. This is probably strictly a function of grain size as this unit predates the metamorphic event.

Foliation trends at about N45E to eastward with a subvertical dip and hence is discordant to most primary structures which have a generally northward strike. The discordant foliation is most prominent in the metasediments underlying Cycle I in eastern Earngey Township and in the intermediate pyroclastic rocks of Cycle II on the east shore of Uchi Lake.

The foliation appears in a qualitative way to parallel the prominent lineation found in the vicinity of the Uchi Mine (Asbury 1975). A roughly concordant foliation is found in the flattened varioles associated with the Cycle II basalts. Schistosity is present in association with large- and small-scale faulting. It is well developed in the peridotite sill 1064 m southeast of Drake Lake. It is prominently developed in the mafic metavolcanics along the north shore of Wabunk Bay of Uchi Lake which mark the Uchi Lake Fault. There are numerous outcrops close to the Uchi Lake Fault which have well developed schistosity such as at the narrows between the northern and southern ends of Uchi Lake, and the peninsula south of the Uchi Lake Lodge.

Slaty cleavage was observed in places in the thicker mudstone beds such as occur associated with Cycle II intermediate pyroclastic rocks on the east shore of Lost Bay.

Gneissosity

Primary magmatic gneissosity or mineral layering is found in the gabbro sills near the old Uchi Mine and in the Leg Lake Sills. Metamorphic gneissosity in the mafic metavolcanics is developed as a contact metamorphic phenomenon within 300 m of the contact with the Okanse Batholith along the south shore of Okanse Lake and along the shores of Perrigo Lake. A weak gneissosity is developed in the granophyric granodiorite as the contact with the surrounding metavolcanics is approached. This gneissosity is defined by slight variations in mafic mineral and quartz phenocryst content. Its origin may be due to magmatic or metamorphic processes.

Lineation

Secondary lineation including minor fold axes, crenulations in foliation, elongated mineral grains and aggregates, elongated clastic and pyroclastic fragments, and spherulites and variolites are present throughout the metavolcanic-metasedimentary and early intrusive units. The lineations are generally in the plane of foliation or bedding and a few representative measurements are plotted on the map.

The lineations form two sets; one, defined by elongation of primary struc-

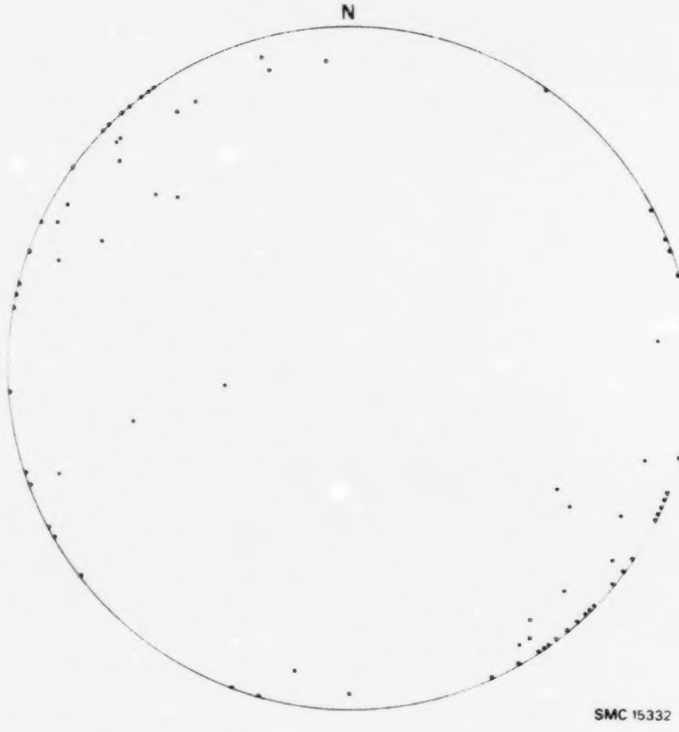

Figure 17–Poles to bedding outside graben.

tures such as variolites, spherulites, and clastic and pyroclastic fragments, is vertical in orientation whereas a second set comprising minor folds, elongated quartz and feldspar grains, and crenulations defines a maximum trending N64E with a plunge of 46 degrees. The first set occurs outside the graben, and the second set within the graben (Figures 17 to 21). The shallow-plunging set is evidence for the graben forming a distinct structural domain in which original bedding directions etc. differed from the area outside the graben.

Boudinage

Slight development of boudinage structures occurs between some of the early quartz veins and the surrounding metavolcanics in the vicinity of the Uchi Mine and in some of the pegmatitic veins cutting the metasediments in eastern Earngey Township. Asbury (1975, p.60, 61) found in a more detailed study of structural geology that most of the boudinage structures between sul-

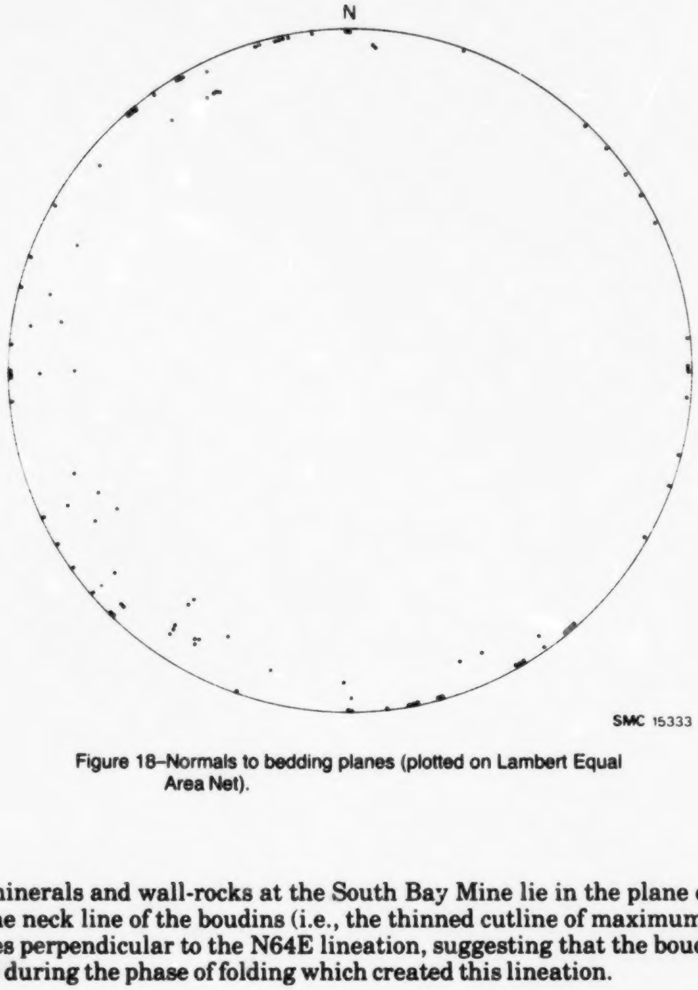

Figure 18–Normals to bedding planes (plotted on Lambert Equal Area Net).

phide minerals and wall-rocks at the South Bay Mine lie in the plane of foliation. The neck line of the boudins (i.e., the thinned cutline of maximum extension) lies perpendicular to the N64E lineation, suggesting that the boudins developed during the phase of folding which created this lineation.

Joints

Joints were measured at scattered locations throughout the map area. Because of space limitations they are not shown on the map face. They are more prevalent in the more brittle rock types such as the felsic and intermediate metavolcanics. The most strongly developed joint set has an observed strike trend of N45E and a dip of 75 to 90 degrees. A secondary set is developed about a trend of N45W with a dip of 65 to 80 degrees. A subhorizontal set is found throughout the central and western part of the map area where it results in large flat slabs 10 to 20 cm thick exfoliating off the surfaces of outcrops of some of the more porous rock types.

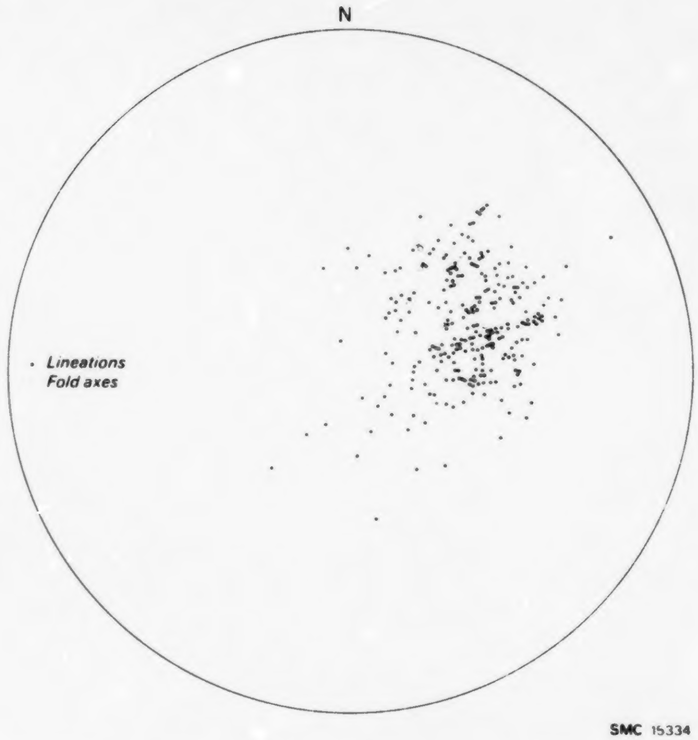

Figure 19–Lineation and fold axis directions in graben (plotted on Lambert Equal Area Net).

Tectonic Events

The metavolcanic-metasedimentary belt has been affected by three major tectonic events, two of which resulted in folding and one in faulting. The first of these was folding of the supracrustal rocks about north-trending, steeply plunging axes. The folding was at first isoclinal in nature in the map area resulting in the series of closely spaced traces of axial planes shown on Figure 4 and the map. Continued compression in the same direction resulted in the formation of a regional anticlinorium centred just east of Leg Lake. A regional synclinorium centred on the west boundary of Earngey Township as proposed by Goodwin (1967 p.42) was also the result of this folding event.

Small-scale folds in the vicinity of the South Bay Mine in Dent Township and western Earngey Township have axial planes trending N64E plunging 40 degrees. The shift in strike of the metavolcanics in this part of the area from north to northeast may simply be a reflection of the change in strike of the units. However, viewing this fold trend in conjunction with the minor flexures

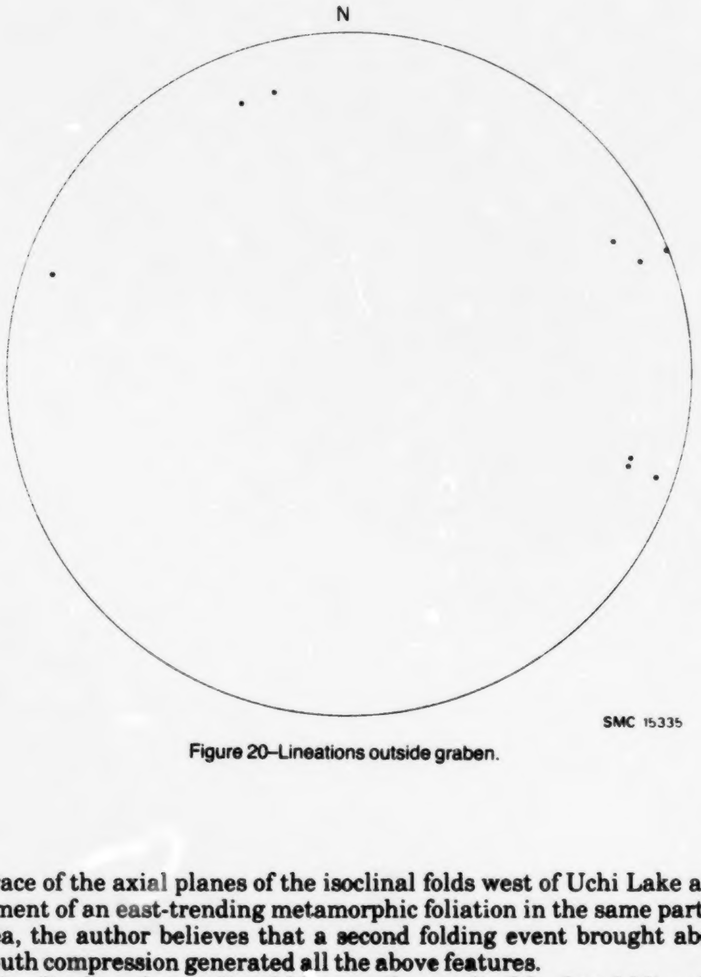

Figure 20–Lineations outside graben.

in the trace of the axial planes of the isoclinal folds west of Uchi Lake and the development of an east-trending metamorphic foliation in the same part of the map area, the author believes that a second folding event brought about by north-south compression generated all the above features.

The isoclinal north-trending folds were the result of the first folding. This is apparent from the fact that the major east-trending folds produced by the diapirism of the late granitic rocks, such as the Okanse Batholith, have a strong axial plane foliation and cleavage which cuts the north-trending folds.

Associated with the second folding event, involving compression in a north-northeast direction was the development of the Uchi Lake Fault, which is a branch of the Sydney Lake cataclastic zone (Breaks and Bond 1975), an east-trending major structural discontinuity extending over 197 km from the shore of Lake Winnipeg in Manitoba (Stone 1976).

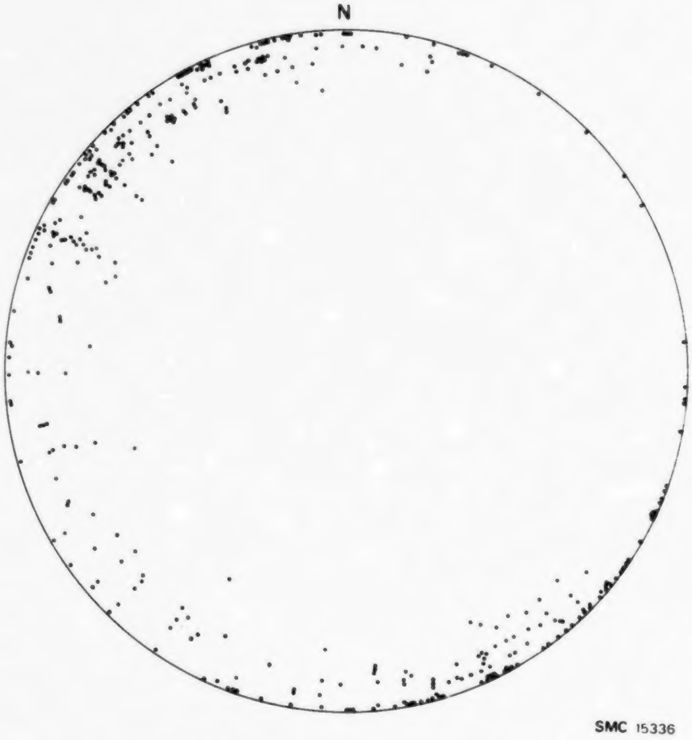

Figure 21–Normals to foliation planes in graben (plotted on Lambert Equal Area Net).

FOLDS

Goodwin (1967, p.42) postulated the existence of a regional synclinorium, the trace of the axial plane of which passes down the middle of the metavolcanic-metasedimentary belt through the western part of the narrows of Confederation Lake and east of Stope Lake, crossing the northwest corner of Agnew Township. To the east of this axis the work of Pryslak (1969; 1970a,b; 1971a,b; 1972a,b) and Goodwin (1967) suggest that the metavolcanic-metasedimentary rocks form a homoclinal succession younging eastward. To the east of this axis, rather than a simple homoclinal succession as suggested by the reconnaissance work of Goodwin (1967), the present survey has established the existence of a more complicated sequence of steeply plunging north-trending isoclinal folds developed on both limbs of a regional-scale anticlinorium centred on the area just east of Leg Lake (see Figure 4).

The isoclinal folds are predicated on the basis of facing-direction criteria such as pillow shape and packing, concentration of amygdules toward the top of pillows and flow top breccia in flows, and primary structures in metasediments and water-laid pyroclastic rocks such as graded bedding, cross-stratification, and bomb-sags. Graded bedding in pyroclastic rocks is not generally a good top indicator in that reversals due to the influx of coarse, newly erupted material can alter an otherwise fining-upward sequence (cf. Macdonald 1972, p.195, 135). However in most places where graded bedding in pyroclastic rocks was used as a facing-direction indicator, the surrounding flows and/or metasediments indicate subaqueous deposition; grain size, bed thickness, and the unimodal character of fragment sizes all indicate distal facies and possibly a turbidite mode of deposition, rendering the facing-direction indicators fairly reliable (cf. Macdonald 1972, p.195).

The trace of the axial plane of an anticline extends from just west of the central part of Uchi Lake northward through the centre of Little Long Lac Mines Limited, Uchi Mine property to at least the northern boundary of Earngey Township. The fold is recognized by opposing pillow tops and the repetition of the Hill-Sloan-Tivey quartz unit which occurs on the western limb. The equivalent on the eastern limb are thin sporadic exposures of oxide facies iron formation shown on Map 2428 (Thurston, in press), intercalated with the gabbros and mafic and felsic flows of Cycle II.

The rocks of Cycle II are folded about a syncline, the trace of the axial plane of which lies east of the Little Long Lac Mines Limited property and extends from the Uchi Lake Fault northward to the boundary of Earngey Township and thence northeastward to the Uchi Lake Fault. Basalts within Cycle II are repeated on either side of the fold axis and westward-facing tops are found in the felsic tuff at the north end of the bay on Uchi Lake to the west of Wabunk Bay.

An anticline centred on the peninsula jutting out from the north shore of Uchi Lake is postulated on the basis of the repetition of a thin basalt unit on the east of the peninsula and 970 m to the west-northwest, and the occurrence of westward-facing tops in the former unit.

Opposing tops in the metasediments underlying Neepawa Bay of Uchi Lake suggest the existence of an anticline in that area. This is also borne out by the occurrence of several west-facing top determinations in the eastern part of the basalt unit just west of Neepawa Bay (see Figure 4). The trace of the axial plane of the anticline is not traceable north of Wabanook Bay.

From the Uchi Lake Lodge, a syncline is traceable through Wabunk Bay of Uchi Lake to the area east of Perrigo Lake.

A syncline lies east of Leg Lake, with the trace of the axial plane passing up the centre of the Leg Lake Sills trending approximately northeastward to a point east of Drake Lake where the fold is cut off by the rocks of the Perrigo Batholith (see Figure 4). This fold is based upon abundant east-facing graded bedding, top determinations in the metasediments along the west side of Leg Lake, and graded bedding facing west in the intermediate tuff interbedded with the basalt east of Leg lake. There appears to be a general equivalence between the basalt and interbedded intermediate tuff east of Leg Lake and the gabbro and diorite west of Leg Lake. The latter are intercalated with abundant intermediate and felsic tuff and may well represent coarse-grained mafic flows. They were mapped as intrusive rocks on the basis of their grain size only.

Continued compression in a generally east-west direction after formation of the closely spaced isoclinal folds in Earngey and Agnew Township resulted in the formation of the anticlinorium centred east of Leg Lake and the synclinorium centred on the South Bay Mine at the top of Cycle III. The evidence for the anticlinorium is summarized in Figure 4, a schematic block diagram drawn along a section line just north of Wabanook Bay from the metasediments in southeastern Earngey Township to the synclinorial axis at the top of Cycle III. The major point in favour of the anticlinorium is that examination of the succession to the southeast and northwest of the anticlinorial axis reveals a progression from mafic flows and mafic to ultramafic intrusive rocks near the centre (east of Leg Lake) to predominantly intermediate pyroclastic rocks away from the centre of the fold at the south end of Uchi Lake and southeast of Leg Lake followed by interbedded metasediments and intermediate pyroclastic rocks just west of Uchi Lake and metasediments southeast of Leg Lake. The anticlinorium also exhibits the expected facies changes from a metasedimentary terrane distant from the volcanic centre high in the stratigraphy in Birkett and eastern Earngey Township and the laterally equivalent but more proximal upper pyroclastic part of Cycle I, for example, along the west side and to the north of Uchi Lake. The proposed anticlinorium has a plunge of unknown magnitude to the southwest. The structural complexity in the eastern half of the metavolcanic and metasedimentary belt as a whole is partially explained by the greater shortening in the eastern half due to granitic diapirs such as the Okanse Batholith, the Perrigo Batholith, and the Allison Lake Batholith (outside map area).

North of Perrigo Lake the mafic flow and hyaloclastic unit form a "J" shaped pattern (outside map area) reminiscent of a fold nose (Thurston, in press). Opposing top determinations are not available, however, west-facing tops in the metasediments just east of the assumed trace of the axial plane and the general symmetry of the distribution of the lithologies would suggest that a syncline exists there, flanked by an anticline on either side.

Work to the north in McNaughton Township (Johns 1979) indicated abundant east-facing tops based upon pillowed shape and packing in the mafic unit on the eastern limb of the syncline, corroborating the interpretation of a syncline. Uniformly west-facing tops through the bulk of the succession in Honeywell Township (Johns 1979) would suggest that an anticlinal axis must exist east of Philchub Lake in Agnew Township. Top determinations based upon pillow shape and packing in the mafic flows on both sides of Philchub Lake serve to define the anticline.

The pattern north of Perrigo Lake outside of the map area is one of a central syncline, flanked by two anticlines as is the pattern south of the Perrigo Batholith in Earngey Township. The eastern anticline may pass to the east of the batholith outside the map area, and the other anticline to the west of the batholith. The trace of the axial plane of the anticlinorium extending north from Leg Lake is cut off by the Perrigo Batholith, conforming to the conventional point of view of diapiric bodies breaching anticlines (McGregor 1951).

A second folding event produced relatively open small-scale folds in the vicinity of the South Bay Mine in Dent Township (Asbury 1975). The main effect of this folding seen in the present map area is a lineation trending N64E and plunging about 40 degrees which is defined by elongated quartz and feldspar grains in outcrops along the west shore of Lost Bay.

As indicated in the section on "Tectonic Events', there is evidence for folding about westward-plunging fold axes in the form of an east-trending foliation and lineation trending 110 to 120 degrees plunging at about 75 degrees west in the vicinity of Uchi Lake.

FAULTS

Faulting is postulated in the map area on the basis of: (1) stratigraphic offsets, (2) zones of shearing and/or schistose rocks or mylonitization, (3) aeromagnetic lineaments (generally negative linear anomalies), and/or (4) offsets in gravity data.

Most of the faults in the map area lie along topographic lows and are not directly observable. Offsets vary from a few centimetres to several hundred metres. Most of the faults are subvertical in dip with the possible exception of the Uchi Lake Fault. More precise location of faults in the metavolcanic-metasediment assemblage was obtained through observation of such features as: (1) alteration such as silicification, epidotization, carbonatization, talc-carbonate alteration of ultramafic rocks, and the presence of sulphide minerals, (2) presence of mylonite zones, (3) the presence of schistosity and brecciation adjacent to topographic lineaments, and (4) offset of rock units and/or metamorphic zones.

Brecciation, schistosity, carbonatization, and silicification are well developed in the area of the Uchi Lake Fault and the fault paralleling the east shore of Wabanook Bay of Uchi Lake.

The most important sets of faults from the point of view of probable magnitude of displacement are those with a north orientation. These strike-slip faults are believed to have developed relatively early because: (1) they are offet by east-west faults, and (2) where one of these faults cuts the Okanse Batholith there is no evidence of mylonitization or brecciation. Evidence from the Sydney Lake area to the south and west of the map area indicates that the extension of the Sydney Lake Fault strike-slip set within the map area has also been subjected to relatively late movement in that there is extensive mylonitization without annealing in the Sydney Lake area. Therefore, there must have been continued activity along the fault (Stone 1976). The major strike-slip fault in the area is herein named the Uchi Lake Fault. It extends from west of Philchub Lake at the south edge of the Okanse Batholith southward through Wabunk Bay of Uchi Lake and the length of Uchi Lake to Wabanook Bay. South of Wabanook Bay, the Uchi Lake Fault is traceable and then bends eastward to just north of Bruce Lake (Breaks *et al.* 1975). Detailed examination of the fault system to the west by D. Stone (1976) has disclosed that the last movement on the fault is strike-slip as is true in this map-area, and that it is dominantly right-lateral. Evidence discussed by Thurston and Breaks (1978) shows that there is also a vertical component to the movement on this fault.

Another major strike-slip fault extends along the east shore of Wabanook Bay of Uchi Lake perhaps as far north as the north end of Leg Lake and south to southeast from Wabanook Bay for at least 5 km. Evidence for this fault includes extensive shearing, a marked topographic lineament, and the offset of the mafic metavolcanics of Cycle II on the east side of the Neepawa Bay anticline. Movement on this fault is probably left-lateral.

A major strike-slip fault extends the length of Leg Lake and thence northeastward along the creek flowing into the northeast end of Leg Lake. The fault is marked by talc-carbonate alteration of the ultramafic rocks, shearing of the peridotite along the creek entering the northeast end of Leg Lake, and slight folding of the metasediments along the west side of Leg Lake. The sense of movement suggested by the folding is right-lateral, however, the amount of displacement, both horizontally and vertically is unknown.

The faults trending at a high angle to strike have widely varying amounts of horizontal displacement, varying from a few centimetres to several hundred metres. The vertical component of movement on these faults is difficult to estimate, but may be appreciable.

An east-northeast-striking fault extends from North Bay of Confederation Lake in Dent Township for 4 km into the northwestern part of Agnew Township. The fault appears to truncate a band of mafic metavolcanics about 1.6 km wide extending down from the north, because south of the fault intermediate metavolcanics predominate. The fault is the locus of a prominent topographic lineament in the map area but due to lack of outcrop convincing displacement of individual units could not be found. The disruption of the gabbro sills shown may simply reflect their original distribution.

The fault extending west from Philchub Lake in Agnew Township appears to displace a magnetic high on Map 872G (Ontario Department of Mines-Geological Survey of Canada 1960). In addition, displacement in a horizontal sense of a thin, poorly exposed intermediate pyroclastic unit amounts to approximately 300 m, with displacement decreasing toward the east end of the structure. Inasmuch as exposure is poor, the area of the fault is marked by a poorly defined airphoto lineament.

An east-striking fault extends N70E for 2.6 km from a lake south of Philchub Lake in Agnew Township. The horizontal component of displacement on this fault is about 75 m based upon offset of a distinctive hyaloclastic unit west of Philchub Lake.

The Bear Lake Fault is part of an extensive topographic lineament observed on LANDSAT (Land Satellite) imagery extending from north of Trout Lake, which is west of the map area, to Slate Lake south of the map area, a distance of 80 km. The fault extends from Fly Lake on the west boundary of Earngey Township through Neepawa Bay of Uchi Lake to the southeastern part of the township, a distance of about 6.4 km. Horizontal displacement on this fault within the map area appears to be left-lateral with a horizontal component of about 2.13 km based upon offset of the mafic-intermediate contact east of Fly Lake.

South of Wabanook Bay are several generally east-trending faults involving relatively minor horizontal displacement of thin marker horizons such as metasedimentary units (Thurston, in press, Map 2428). There is not enough exposure to be able to correlate units on either side of the faults with sufficient certainty to estimate horizontal displacements.

Strain

An interesting problem with respect to the amount of mechanical strain the rocks of the map area have undergone has yet to be resolved. Objects such as clasts in pyroclastic rocks and metasediments and varioles in the basalts of Cycle III have a prominent vertical elongation of about 2:1. In addition, the varioles are slightly elongated perpendicular to regional bedding. By analogy with the analysis of P.G. Hudleston (1976), the elongation perpendicular to bedding is due to the east-trending second folding, a much less intense event than the isoclinal north-trending folding which so dramatically elongates the variolites in the vertical direction.

It should be noted that the mineral lineations as near as 1.6 km in the South Bay Mine area trend N64E plunging at about 40 degrees (Asbury 1975). The N64E trending lineations form a second set suggesting early foundering of a central sector graben.

ECONOMIC GEOLOGY

This section attempts to integrate the overall model of cyclical volcanism with the economic geology of the map area.

Cycle I

No known major mineral occurrences are associated with Cycle I metavolcanics in the map area.

Cycle II

The basalts of Cycle II are host to several gold occurrences along strike with the HST (Hill-Sloan-Tivey) chert. The chert caps a sequence of air-fall rhyolite tuffs forming the upper part of a minor-cycle within Cycle II. Hydrothermal activity beneath the chert was intense. Evidence for this consists of massive leaching of alkalies from tuff samples taken a few centimetres beneath the chert relative to samples taken a few metres below the chert (cf. Thurston 1978; Fryer *et al.* 1979). As well O isotopic determinations on the HST chert (Thurston 1981, Appendix) show the chert was precipitated from water at ≅220°C. The centre of hydrothermal activity was apparently in the vicinity of the Uchi Gold Mine, inasmuch as a network of quartz veins is well developed in that area. On the west limb of the synclinorium within the map area, the Cycle II basalts are zoisitized, as a result of hydrothermal introduction of Ca (cf. Humphris and Thompson 1978), mainly along the shores of Narrow Lake. The author suggests that the presence of this leaching and the Duncan and Vihhonen gold prospects in Skinner Township, as well as the Bathurst prospect, outside the map area in northern Skinner Township, make this part of the map area an excellent target for As and Sb geochemistry as a means of selecting altered basalts for more intense gold exploration (Pirie 1981).

The upper part of Cycle II consists of rhyolitic pumiceous pyroclastic rocks, overlain by a stromatolitic carbonate in turn overlain by chert. The chert is reported (Resident Geologist's Files, Ontario Ministry of Natural Resources, Red Lake, Ontario) to contain pyrrhotite-rich sections. By analogy with the Agnico Eagle deposit in Quebec (Barnett and Hutchinson 1978) this unit may represent a good Au exploration target.

Cycle III

The basalts of Cycle III include two Fe-enrichment cycles, each capped by a variolitic unit. The lower Fe-enrichment cycle is capped by a massive variolitic flow (Thurston 1978). Rubble on surface in the vicinity of the New York Oils and Mines gold prospect contains (Thurston, in press) some pebbles of graphitic metasediment containing 50 to 80 percent massive pyrite. Assay of this material yielded 140 to 170 ppb Au (Geoscience Research Laboratory, Ontario Geological Survey, Toronto), suggesting that this horizon, of unknown thickness, which probably overlies the variolitic unit, and which marks a hiatus in volcanism, may be the locus of the gold mineralization.

On the west limb of the synclinorium the J-M Mine, a past producer (27,142 oz. Au; 18,251 oz. Ag; Ferguson *et al.* 1971, p.205) occurs at about the same stratigraphic level. Based on Bateman's (1940b) description, the main ore system may be similar to the above described exhalative metasediment.

Throughout Cycle III basalts, zoisitization and chloritization (Thurston 1978; Thurston and Fryer, in press) are extensive, but assumed to be premetamorphic in that the alteration is generally more intense at pillow margins where it has not pervaded the whole pillow (Thurston 1978). This sort of alteration signifies premetamorphic hydrothermal activity (cf. McGeehan 1978; Fryer and Hutchinson 1976) which may in part represent the source of the scattered Au mineralization in Cycle III basalts. Note that hydrothermal systems involved in massive sulphide deposit generation are generally smaller (Kerrich 1981; Fryer *et al.* 1979).

The felsic metavolcanics of Cycle III are host to a syngenetic volcanogenic massive sulphide orebody, the South Bay Mine of Selco Incorporated (Pollock *et al.* 1972). The hydrothermal circulation system related to the formation of the orebody extends only a few kilometres into the surrounding felsic metavolcanics, producing anomalous concentrations of sericite after plagioclase, carbonate, and pyrite (Sopuck 1977).

Trace element geochemistry of Cycle III felsic metavolcanics disclosed unusual flat REE patterns for the rhyolites. These patterns are most probably related to genesis of the rhyolites by partial melting of sialic crust, enriching the liquid in REE and hologens (Thurston and Fryer, in press). Possible alternatives viewed as less likely are liquid immiscibility, the petrogenetic mechanism for Cycle III rhyolites (Thurston and Fryer, in press) or, to large-scale complexing by CO_3^{-2} and Cl^- rich fluids of the heavy REE, enriching the rhyolites in the heavy REE. Thurston (1980b) analyzed mineralized and unmineralized rhyolites from the Abitibi Subprovince and found heavy REE enrichment to be associated with mineralized samples only.

In terms of physical volcanological processes, Cycle III rhyolites are mainly deposited within the sector graben formed during an episode of resurgent caldera activity. The association of Cu-Zn Kuroko-type ores with resurgent caldera activity is well known (Harley 1978).

The South Bay orebody occurs at the contact of the rhyolitic quartz-feldspar porphyry endogenous dome (Pollock *et al.* 1972) and overlying rhyolitic tuff-breccia derived from phreato-magmatic explosions of dome material and dome-collapse breccia. The ore occurs in several lenses (Thurston *et al.* 1978) along the contact and is in places underlain by a chloritic alteration pipe termed QFP II by the mine personnel (Thurston *et al.* 1978).

Further exploration is warranted within the Cycle III sector graben, but given the many relatively small-scale changes in strike, exploration methodology must take this into account in orientation of geophysical lines and orientation of drillholes, particularly in the area west of Fly Lake.

SUMMARY AND CONCLUSIONS

Summary

The rocks of the Confederation Lake area form three mafic to felsic volcanic cycles. Each cycle begins with pillowed subaqueous basalt to andesite flows, and grades upward into dacite to rhyolite which occur predominantly as pyroclastic rocks. The map area has relatively proximal facies metavolcanics compared to relatively distal facies metavolcanics, and coeval dominantly sedimentary accumulations of the English River Subprovince. The large-scale structure of the Confederation Lake area is interpreted as a medial synclinorium with an anticlinorium on the east side of the belt. The anticlinorium has been produced by thrusting.

Cycle I is comprised of 2500 m of pillowed mafic subaqueous flows and about 2700 m of intermediate ignimbrites, debris flows, and minor air-fall tuff succeeded upward by about 300 m of felsic ignimbrites.

Cycle II includes a basal 2300 m of amygdaloidal pillowed basalt to andesite flows of subaqueous origin on the west limb of the fold. Correlative with this on the east limb there are four 150 to 200 m thick minor-cycles ranging from subaqueous pillowed basaltic andesite to air-fall rhyolite tuff. Overlying these rocks on both limbs of the fold there are several subaqueous intermediate ignimbrites and minor intercalated flows grading upward from pumice conglomerate to fine tuff interbedded with subaqueous debris flows. Two subaerial ignimbritic flow units of tuff, lapilli-tuff, and tuff-breccia are succeeded by 60 m of shallow water marble. About 200 m of correlative felsic pumiceous subaqueous ignimbrite occurs on the east limb.

Cycle III has a base of 3400 to 5500 m of pillowed subaqueous basalt to andesite flows with two variolitic horizons on the west limb. This is somewhat thinner on the east limb and is overlain by 2000 m of intermediate to felsic ash flows. It is broken by the sector graben which contains 1500 m of felsic flows and 450 m of ash flows with minor intercalated air-fall material, all of Cycle III. This is succeeded by 200 m of debris flows and a 60 m thick mafic flow. A complex of felsic flows, pyroclastic rocks, and the endogenous dome at the South Bay Mine are at the top of the sequence.

The basalts of all three cycles are tholeiitic, whereas the upper intermediate to felsic parts of each cycle show calc-alkalic trends. The basalts are olivine normative in Cycle I and variably olivine and quartz normative in Cycles II and III. Alteration involving additions of Mg, Ca, and Na is described for some basalts in each cycle.

Ti as an index of fractionation suggests basalts of all cycles have experienced enrichment of Fe, V, Sc, Co, Zr, and Y and a depletion of Ca, Al, Sr, and Mg which indicate crystallization of olivine, plagioclase, and, late in the Fe-enrichment cycle, clinopyroxene.

The basaltic liquids evolve in composition from olivine normative tholeiites in Cycle I to variably quartz and olivine normative tholeiites to high alumina tholeiites in Cycle III. This evolution is also marked by successively higher Y and Zr contents. The basaltic liquid of Cycle III entered a region of liquid immiscibility.

Basaltic andesite and andesite intercalated with the basalts of Cycles I and II are of two types: those with flat REE patterns and those with fractionated REE patterns. Basaltic andesites and andesites associated with the minor-cycles exhibit:

1. flat REE patterns
2. heavy REE enriched
3. heavy REE depleted concave downward REE pattern

Felsic rocks of each cycle are dacite to rhyolite and form two groups: a heavy REE depleted group and a heavy REE enriched group. Interrelations of abundances of Ca, Al, Cr, Ni, Zr, Y, Nb, K, and so on suggest that most felsic metavolcanics within any one cycle are related by fractionation of plagioclase, K-feldspar, quartz, and biotite.

Felsic metavolcanic rock types in Cycle I evolve to more siliceous differentiates resulting in a slow rise of Y and Zr values. Cycle II felsic metavolcanics show a low Y and Zr trend typical of Cycle I, and a trend involving higher contents of Y and Zr. Cycle III felsic metavolcanics have only the high Y and Zr trend.

Fractional crystallization is responsible for differentiation within the basaltic sequences and has brought about most of the dacite to rhyolite transitions but the process is not responsible for the basalt to rhyolite trend within each cycle. Other petrogenetic mechanisms must have been active.

The heavy REE enriched andesites were produced by mixing of tholeiitic basalt and trondhjemite and the flat REE pattern andesites were produced by mixing of tholeiite and rhyolites with low heavy REE contents (3) above. Cycle II felsic magmatism is viewed as initial production of heavy REE depleted rhyolite by partial melting of amphibolite, followed by magma mixing producing violent Plinian activity (cf. Sparks *et al.* 1977) which resulted in the overlying felsic volcanics with flat to heavy enriched patterns.

Liquid immiscibility produced the variolitic basalts of Cycles II and III, minor amounts of felsic volcanic rocks in Cycle II and possibly the dacites and rhyolites of Cycle III. The most likely petrogenetic process for Cycle II and III rhyolites involves a compositionally zoned siliceous magma chamber with mantle-derived basaltic melts providing heat to melt surrounding sial which mixes with the basalt and evolves to form a chamber with a rhyolitic upper part (cf. Hildreth 1979).

Conclusions

1. Cyclical volcanism in the Confederation Lake area consists of three basalt to rhyolite cycles, corresponding to the major-cycle and minor- and mini-cycle scales of Anhaeusser (1971).

2. Cycle I represents eruption in a shallow water environment from a shield volcano of mafic flows followed by Plinian eruption of felsic ignimbrites. In Cycle II, rocks of the Narrow Lake area on the west limb of the fold represent a relatively proximal environment for both basalt and andesite flows and the overlying pyroclastic rocks.

The intermediate pyroclastic sequence above the basaltic flows commenced as a mixture of proximal subaqueous ignimbrites and debris flows with minor flows, capped by two ignimbrite flow units which form a single cooling unit. The minor-cycles of formation F represent another volcanic source based upon chemistry and facies analysis.

Cycle II activity commenced with quiet effusion of nonviscous basalt and andesite. Later pyroclastic rocks were the result of Plinian eruptions into relatively gentle volcanic slopes. In a large-scale sense this pattern represents formation of a Krakatoan caldera which did not progress to the resurgent stage.

Cycle III volcanism commenced with quiet extrusion of basalt flows, followed by Plinian eruptions of felsic ash flows and flows, and finally, development of a sector graben filled with later flows, ignimbrites, and debris flows.

3. The style of volcanism evolved from cycle to cycle, with Cycle I marked by construction of a shield volcano, Cycle II by construction of a shield volcano which evolved into Stage II of the Smith and Bailey (1968) caldera cycle, and Cycle III, involving a similar edifice which proceeded through a full caldera cycle including resurgence and later hydrothermal activity.

4. There are Fe-enrichment cycles in the basalts caused by fractional crystallization of olivine, plagioclase, and minor clinopyroxene. Si-enrichment in dacites and rhyolites is caused by fractional crystallization of plagioclase, quartz, K-feldspar, and biotite.

5. The variety of petrogenetic processes involved (Thurston and Fryer in press), and their interrelationships suggest that cyclical volcanism is a complex interplay of fractional crystallization of an originally mantle-derived liquid, followed by various types of magma mixing, remelting of basaltic rocks, and liquid immiscibility.

6. Cyclical volcanism in the Confederation Lake area took place over an appreciable span of time as Cycle I rhyolites are 2958.6 ± 1.7 Ma, Cycle II rhyolites are 2794 ± 6 Ma, and Cycle III rhyolites are 2739 ± 31 Ma.

7. The preferred tectonic model for this Archean volcanic sequence is a back arc basin similar to that of Tarney *et al.* (1976).

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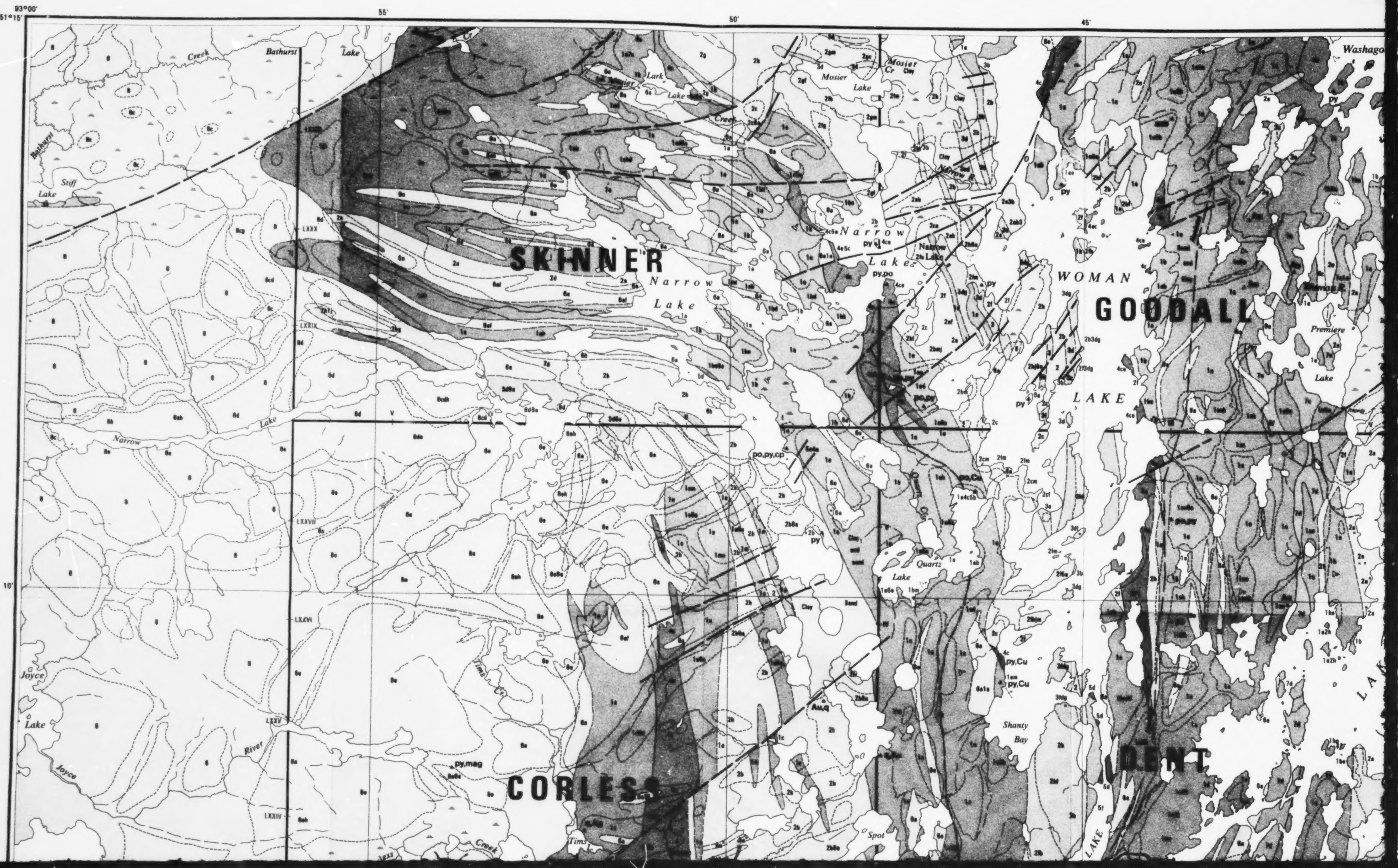
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SKINNER
GOODALL
CORLESS
DENT
Bathurst Lake
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Stiff Lake
Lark Lake
Mosier Lake
Mosier Cr
Creek
Narrow Lake
Narrow R.
WOMAN LAKE
Washago
Premiere Lake
Quartz Lake
Quartz Cr
Shanty Bay
Spot Lake
Tims Cr
Tims L.
Joyce Lake
Joyce River
Creek
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LXXIX
LXXVII
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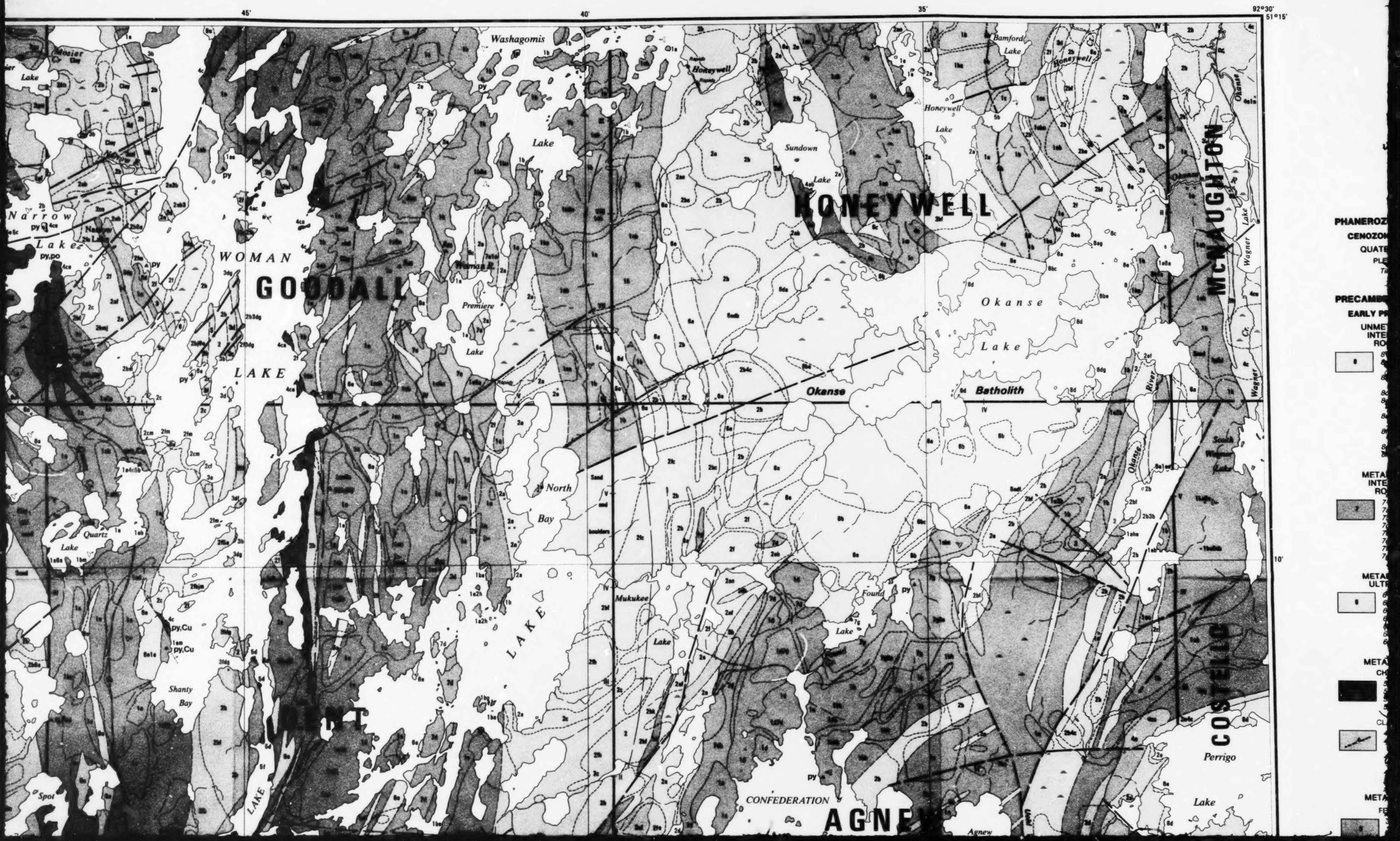
Sand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Lake
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Honeywell
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Sundown
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HONEYWELL
MCNAUGHTON
Okanse
Okanse
Lake
Wagner
Lake
Wagner
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Narrow
Lake
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WOMAN
GOODALL
LAKE
Woman R.
Premiere
Lake
Okanse
Batholith
North
Bay
Sand
and
boulders
Quartz
Lake
Shanty
Bay
Spot
LAKE
DENT
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Mukukee
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Lake
Okanse
River
South
Wagner
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Perrigo
Lake
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QUATE
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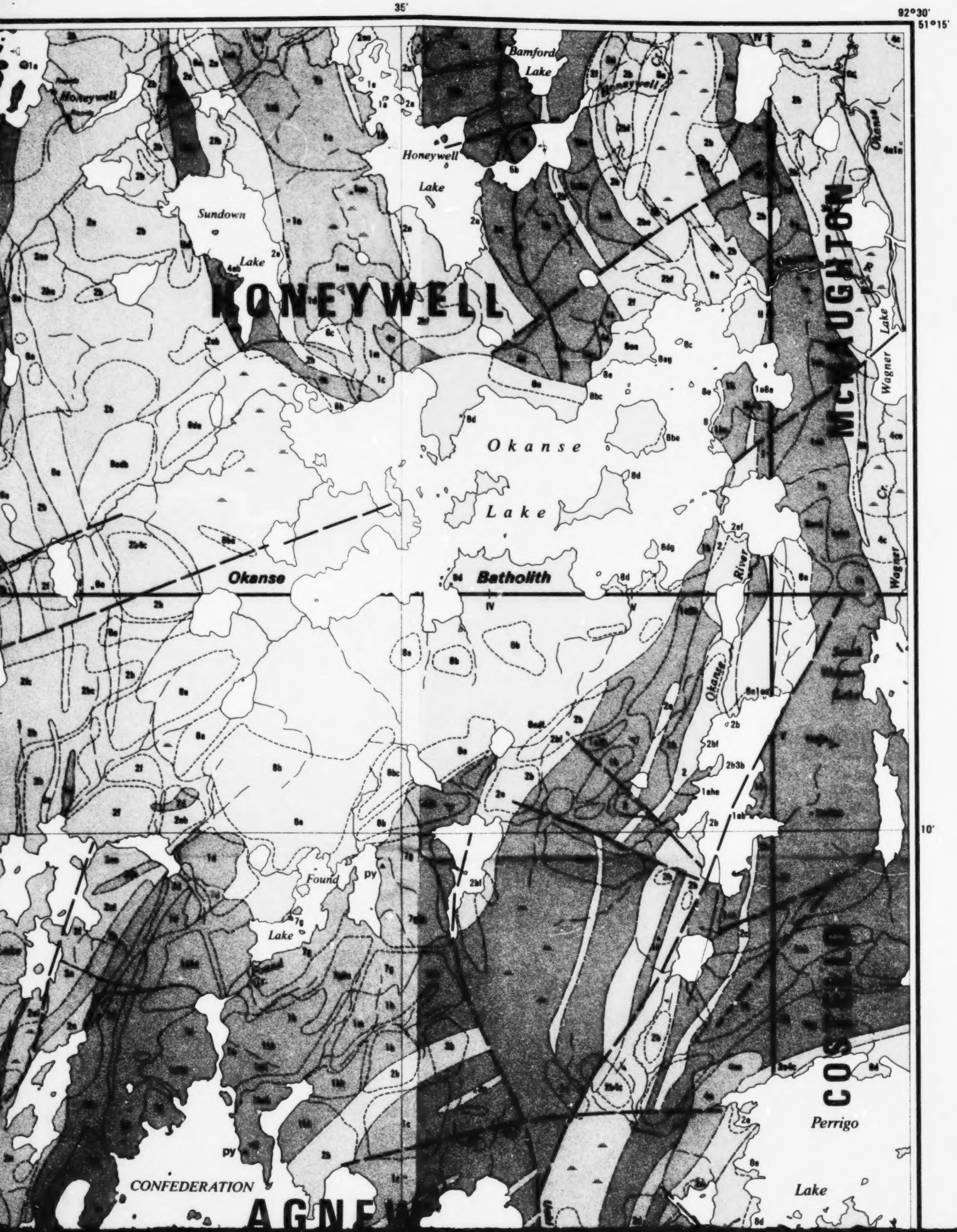
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Honeywell Lake
Sundown Lake
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MCNAUGHTON
Okanse Lake
Okanse Batholith
Wagner Lake
Okanse Cr.
River
Found Lake
COSTELLO
Perrigo Lake
CONFEDERATION
AGNEW

Ministry of Natural Resources
Ontario

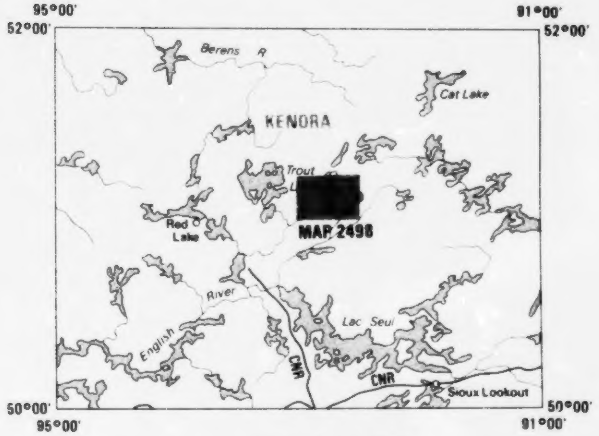
Ontario Geological Survey

Map 2498

CONFEDERATION LAKE

PRECAMBRIAN GEOLOGY

Scale 1:50 000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Berens R.
Cat Lake
KENORA
Trout L.
Red Lake
MAP 2498
River
English
Lac Seul
CNR
CNR
Sioux Lookout
50°00'
95°00'
50°00'
91°00'

Aeromagnetic reference 872G

NTS reference 52N/2

Published 1984

LEGEND

PHANEROZOIC

CENOZOIC

QUATERNARY

PLEISTOCENE AND RECENT

Till, clay, sand and gravel.

UNCONFORMITY

PRECAMBRIAN

EARLY PRECAMBRIAN (ARCHEAN)

UNMETAMORPHOSED FELSIC TO INTERMEDIATE INTRUSIVE ROCKS[a]

8 *Unsubdivided.*
8a *Amphibole diorite, syenodiorite, (porphyritic).*
8b *Amphibole trondhjemite, quartz diorite (porphyritic).*
8c *Biotite trondhjemite, quartz diorite.*
8d *Amphibole quartz monzonite, granodiorite.*
8e *Biotite quartz monzonite, granodiorite (porphyritic).*
8f *Amphibole phenocrysts and/or mafic inclusions.*
8g *Intrusion breccia.*
8h *Pegmatite.*

INTRUSIVE CONTACT

METAMORPHOSED FELSIC TO INTERMEDIATE INTRUSIVE ROCKS

7 *Unsubdivided.*
7a *Felsic quartz porphyry.*
7b *Quartz-feldspar porphyry.*
7c *Feldspar porphyry.*
7d *Granophyric granodiorite.*
7e *Intermediate quartz porphyry.*
7f *Biotite sericite granodiorite.*
7g *Chloritic granodiorite.*

INTRUSIVE CONTACT

METAMORPHOSED MAFIC AND ULTRAMAFIC INTRUSIVE ROCKS

6 *Unsubdivided.*
6a *Gabbro.*
6b *Diorite, quartz diorite.*
6c *Serpentinized pyroxenite.*
6d *Serpentinized peridotite.*
6e *Serpentinized dunite.*
6f *Porphyritic mafic intrusive rocks.*

INTRUSIVE CONTACT

METASEDIMENTS

CHEMICAL METASEDIMENTS[b]

5a *Chert.*
5b *Ironstone—oxide facies.*
5c *Ironstone—sulphide facies.*
5d *Marble.*

CLASTIC METASEDIMENTS[b]

4 *Unsubdivided.*
4a *Pebble and cobble conglomerate (matrix supported).*
4b *Granule conglomerate (matrix supported).*
4c *Wacke.*
4d *Feldspathic wacke, arkose.*
4e *Argillite, siltstone.*

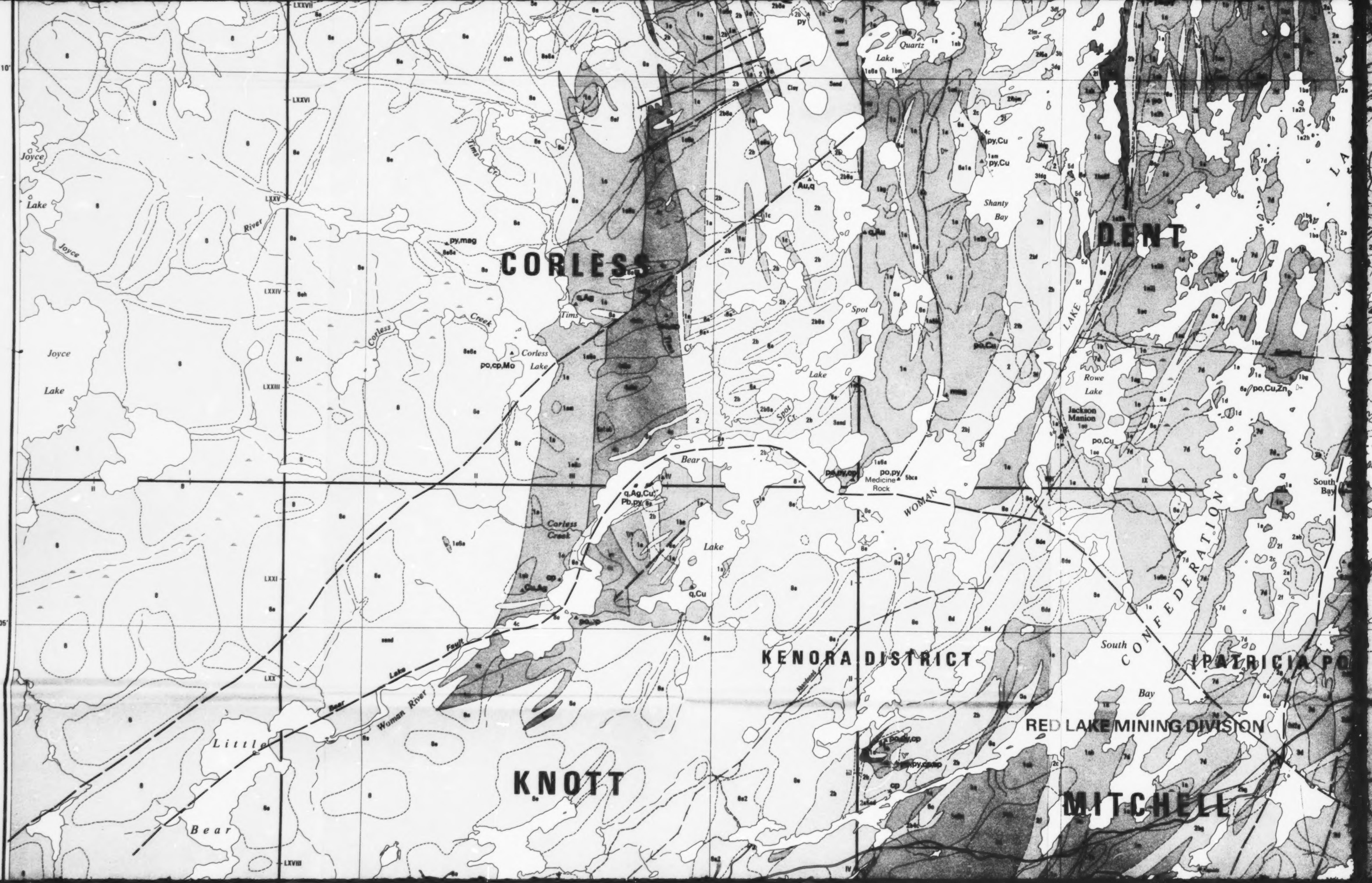
METAVOLCANICS

FELSIC METAVOLCANICS[b]

3 *Unsubdivided.*

Motor road, with Provincial Highway number if applicable 642
Minor road, surface condition variable
Trail, winter road or portage
Railway
Electric power transmission line
Building, built-up area
Elevation in feet 1144
Pit (sand, gravel)
Esker

International, provincial boundary approximate position only
Regional municipality, territorial district boundary approximate position only
Geographic township boundary, base or meridian line with milepost, approximate position only
Surveyed line, approximate position only
Mining Division, boundary approximate position only
Indian Reserve, Provincial Park, boundary approximate position only
Swamp, inundated land


CORLESS
DENT
KNOTT
MITCHELL
KENORA DISTRICT
PATRICIA PO
RED LAKE MINING DIVISION
CONFEDERATION
LAKE
Joyce Lake
Joyce River
Joyce Lake
Tims Cr.
Tims Creek
Corless Creek
Corless Lake
Corless Creek
Quartz Lake
Spot Lake
Spot Cr.
Shanty Bay
Bear Lake
Medicine Rock
WOMAN
Rowe Lake
Jackson Manion
South Bay
South Bay
Bear Lake Fault
Woman River
Little
Bear
10'
05'
py,mag
po,cp,Mo
q,Ag
Au,q
q,Au
py,Cu
py,Cu
po,Cu
q,Ag,Cu,Pb,py
Cu,Ag
cp
q,Cu
po,py,cp
po,py
po,Cu
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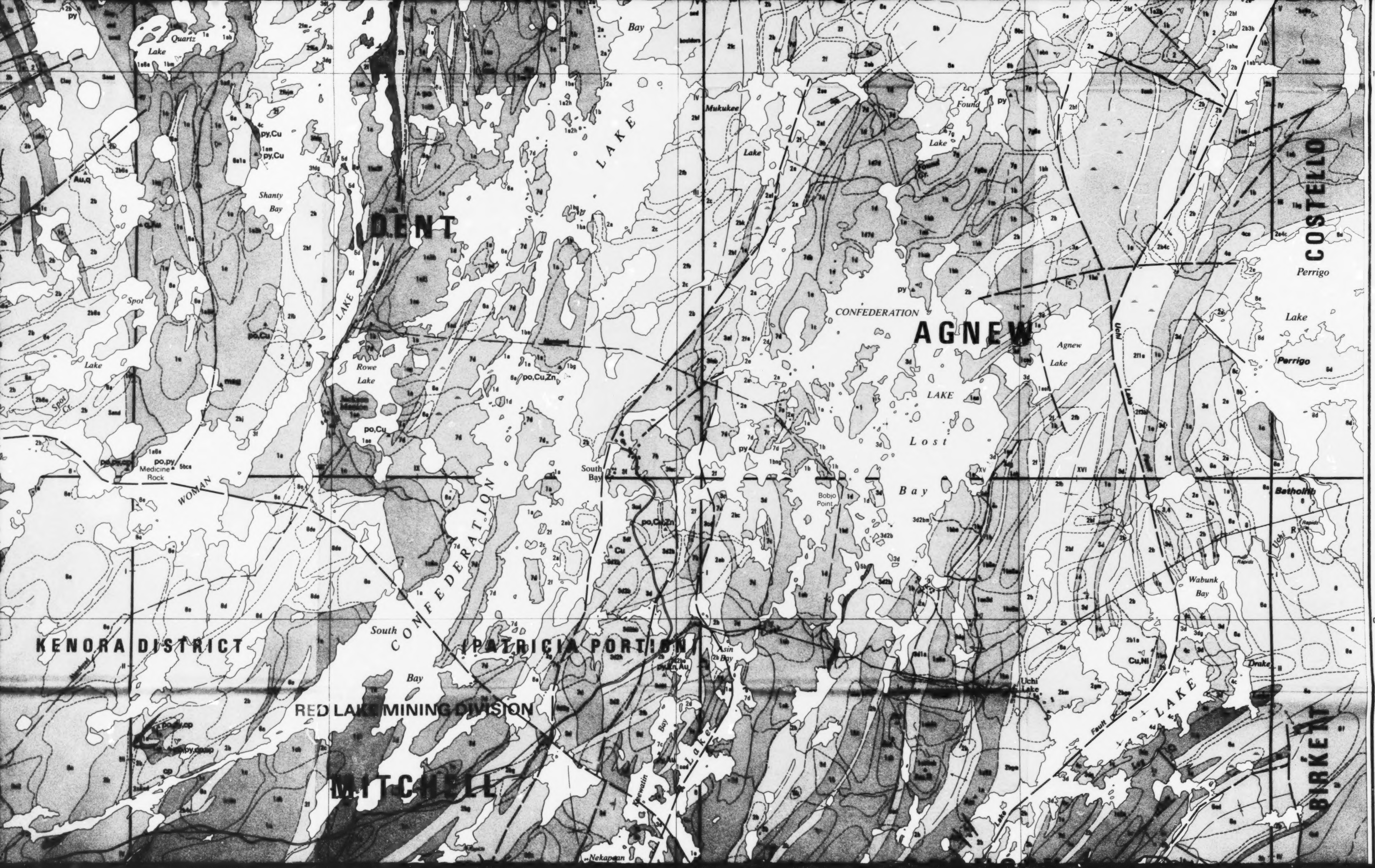
LXXIV
LXXIII
LXXI
LXX
LXVIII
IX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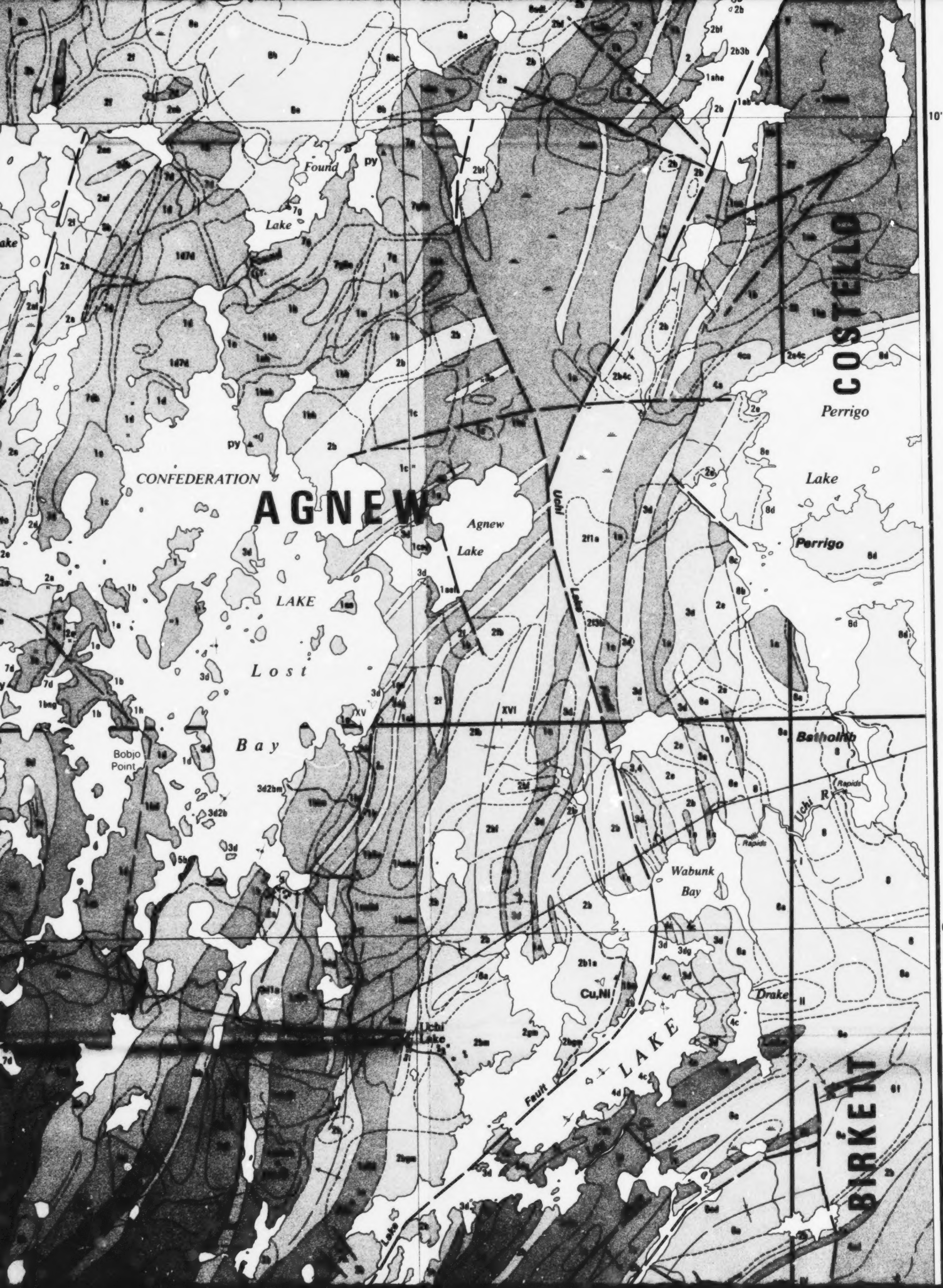
CONFEDERATION
Quartz Lake
Shanty Bay
Spot Lake
Spot Cr.
Medicine Rock
WOMAN
Rowe Lake
Dent Lake
South Bay
Mukukee Lake
Found Lake
Found Cr.
Agnew Lake
Lost Bay
Bobjo Point
Perrigo Lake
Perrigo
Betholite
Uchi Lake
Uchi R.
Rapids
Wabunk Bay
Drake
Fault
Asin Bay
Keewatin Bay
Nekapaan
10'
05'
py
py,Cu
po,Cu
po,py,cp
po,Cu,Zn
po,Cu
Cu
Cu,Ni
Au,q
py,cp,Au
XV
XVI
IX
IV



NTS reference 52N/2

Published 1984

INTERMEDIATE INTRUSIVE ROCKS

7
- 7 Unsubdivided.
- 7a Felsic quartz porphyry.
- 7b Quartz-feldspar porphyry.
- 7c Feldspar porphyry.
- 7d Granophyric granodiorite.
- 7e Intermediate quartz porphyry.
- 7f Biotite sericite granodiorite.
- 7g Chloritic granodiorite.

INTRUSIVE CONTACT

METAMORPHOSED MAFIC AND ULTRAMAFIC INTRUSIVE ROCKS

6
- 6 Unsubdivided.
- 6a Gabbro.
- 6b Diorite, quartz diorite.
- 6c Serpentinized pyroxenite.
- 6d Serpentinized peridotite.
- 6e Serpentinized dunite.
- 6f Porphyritic mafic intrusive rocks.

INTRUSIVE CONTACT

METASEDIMENTS

CHEMICAL METASEDIMENTS[b]

- 5a Chert.
- 5b Ironstone—oxide facies.
- 5c Ironstone—sulphide facies.
- 5d Marble.

CLASTIC METASEDIMENTS[b]

- 4 Unsubdivided.
- 4a Pebble and cobble conglomerate (matrix supported).
- 4b Granule conglomerate (matrix supported).
- 4c Wacke.
- 4d Feldspathic wacke, arkose.
- 4e Argillite, siltstone.

METAVOLCANICS

FELSIC METAVOLCANICS[b]

3
- 3 Unsubdivided.
- 3a Massive flows.
- 3b Porphyritic flows.
- 3c Spherulitic flows, minor tuffs.
- 3d Tuff, lapilli-tuff.
- 3e Sericite schist.
- 3f Pyroclastic breccia, tuff-breccia.
- 3g Thin-bedded units.

INTERMEDIATE METAVOLCANICS[b]

2
- 2 Unsubdivided.
- 2a Massive flows.
- 2b Tuffs.
- 2c Porphyritic flows.
- 2d Pillowed flows.
- 2e Spherulitic flows, tuffs.
- 2f Tuff-breccia, pyroclastic breccia.
- 2g Tuff, lapilli-tuff.
- 2h Chlorite-sericite schist, biotite-chlorite-sericite schist.
- 2j Thin-bedded units.
- 2k Medium-bedded units.
- 2m Thick-bedded units.

MAFIC METAVOLCANICS[b]

1
- 1 Unsubdivided.
- 1a Massive flows.
- 1b Pillowed flows.
- 1c Porphyritic flows.
- 1d Variolitic flows.
- 1e Amygdaloidal flows.
- 1g Flow breccia.
- 1h Pillow breccia, hyaloclastic rocks.
- 1j Chlorite, biotite-chlorite schists.
- 1k Carbonatized.
- 1m Pyroclastic rocks.
- 1n Autoclastic breccia.

S Sulphide mineralization.

Where in places a formation is too narrow to show in colour and must be represented in black, a short black bar appears in the appropriate block.

[a] *Subdivision of major rock units does not indicate age relationships.*

[b] *Age relationships between units 1,2,3,4 and 5 are unknown.*

METAL AND MINERAL REFERENCE

Motor road, with Provincial Highway number if applicable	(642)
Minor road, surface condition variable	
Trail, winter road or portage	
Railway	
Electric power transmission line	
Building, built-up area	
Elevation in feet	1144
Pit (sand, gravel)	
Esker	

- *International, provincial boundary approximate position only*
- *Regional municipality, territorial district boundary approximate position only*
- *Geographic township boundary, base or meridian line with milepost, approximate position only*
- *Surveyed line, approximate position only*
- *Mining Division boundary approximate position only*
- *Indian Reserve, Provincial Park, boundary approximate position only*
- *Swamp, inundated land*

SYMBOLS

- *Small bedrock outcrop.*
- *Area of bedrock outcrop.*
- *Bedding, top unknown, (inclined, vertical).*
- *Bedding, top indicated by arrow; (inclined, vertical, overturned).*
- *Bedding, top (arrow) from grain gradation; (inclined, vertical, overturned).*
- *Bedding top (arrow) from cross bedding; (inclined, vertical, overturned).*
- *Lava flow; top (arrow) from pillows shape and packing.*
- *Geological boundary, position interpreted.*
- *Geological boundary, deduced from geophysics.*
- *Lineament or fault.*
- *Anticline, syncline, with plunge.*
- *Vein.*
- *Past producing mine.*
- *Mineral occurrence.*

PAST PRODUCING MINES

1	*Hudson-Patricia Gold Mines Ltd.**	Au,Ag
2	*Little Long Lac Mines Ltd. (Uchi Mine)*	Au,Ag

MINERAL PRODUCTION AND RESOURCES

The map area includes 3 past-producing gold mines, two in the basalts of Cycle III and one in a quartz vein system and chert of the minor cycles on the east limb of Cycle II. Production for these mines was:

Northgate Exploration Ltd., (J-M Consolidated Mine) 25814 oz. gold, 12333 oz. silver

Blue, M.F. (Hudson-Patricia Mine) 18571 oz. gold, 305 silver

Little Long Lac Gold Mines Ltd. (Uchi Mine) 114,467 oz. gold, 14,345 oz. silver

Selco Mining Corp. Ltd. operated a copper-zinc-silver mine at South Bay of Confederation Lake from 1970 to 1981, producing 68519 tons copper concentrate, 226,287 tons zinc concentrate and 156,212 oz. silver from 1,637,948 tons or ore.

Gold occurrences are numerous, particularly associated with the minor cycles of Cycle II east of Lost Bay of Confederation Lake, but as well, several occurrences are found along Narrow Lake in Cycle II basalt on the west limb of the fold. There are several gold occurrences described in various parts of Cycle II on the west limit of the fold (Map 2428). Base-metal occurrences of note occur south of the South Bay Mine in Cycle III volcanic rocks.

The area includes occurrences of asbestos, silver, gold, copper, iron, molybdenum, nickel, lead and zinc. Further information on these occurrences may be obtained from assessment files maintained at the Geoscience Data Centre, Ontario Geological Survey, Toronto or the resident geologist's office, Ont. Ministry of Natural Resources, Red Lake. Details on these occurrences may be found in OGS geological reports numbered 177, 234 and 236.

SOURCES OF INFORMATION

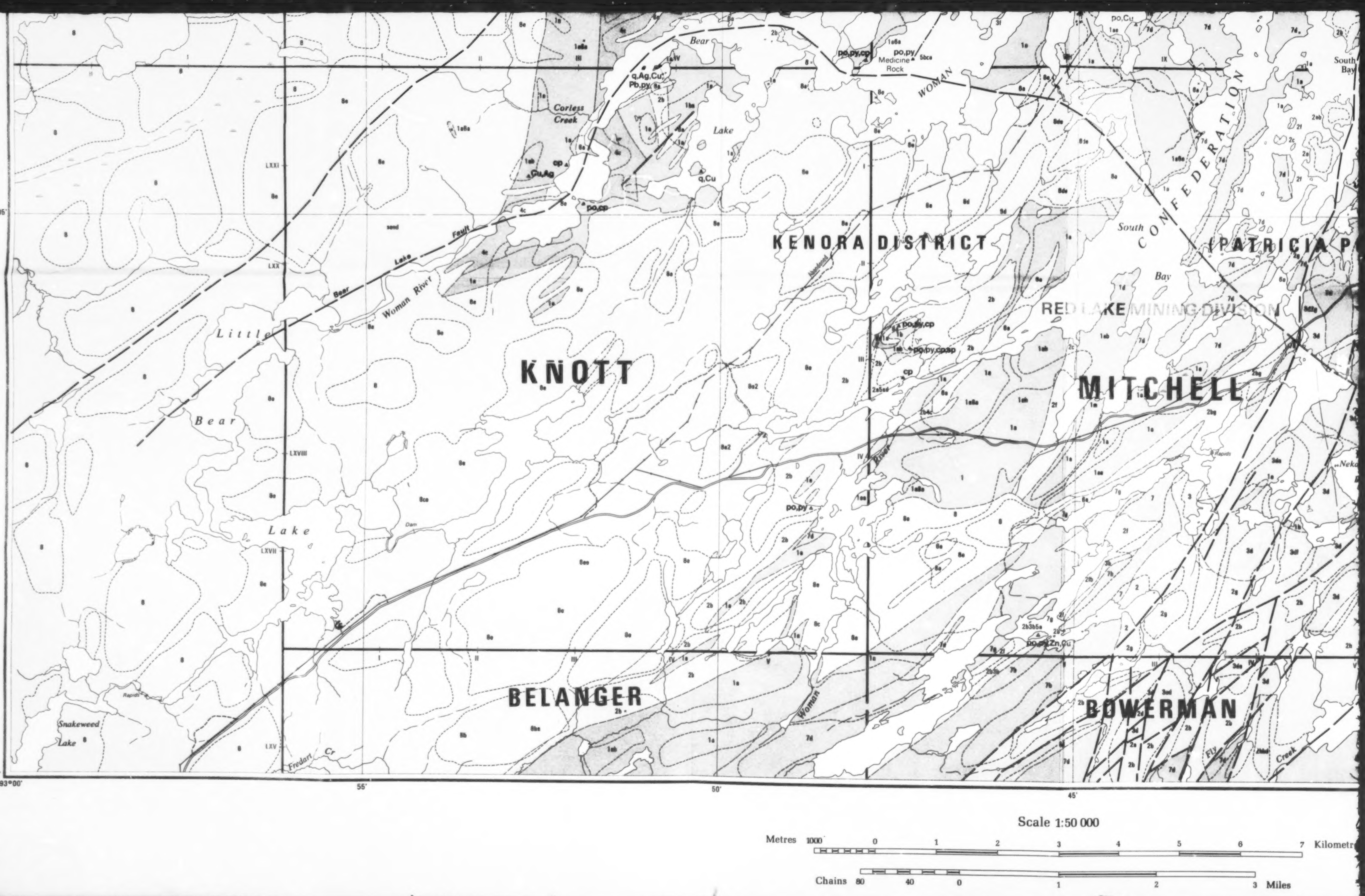
Geology from published and unpublished maps of the Ontario Geological Survey, Ministry of Natural Resources and supplementary mapping by P.C. Thurston and assistants 1975-6.
Geology is not tied to surveyed lines.

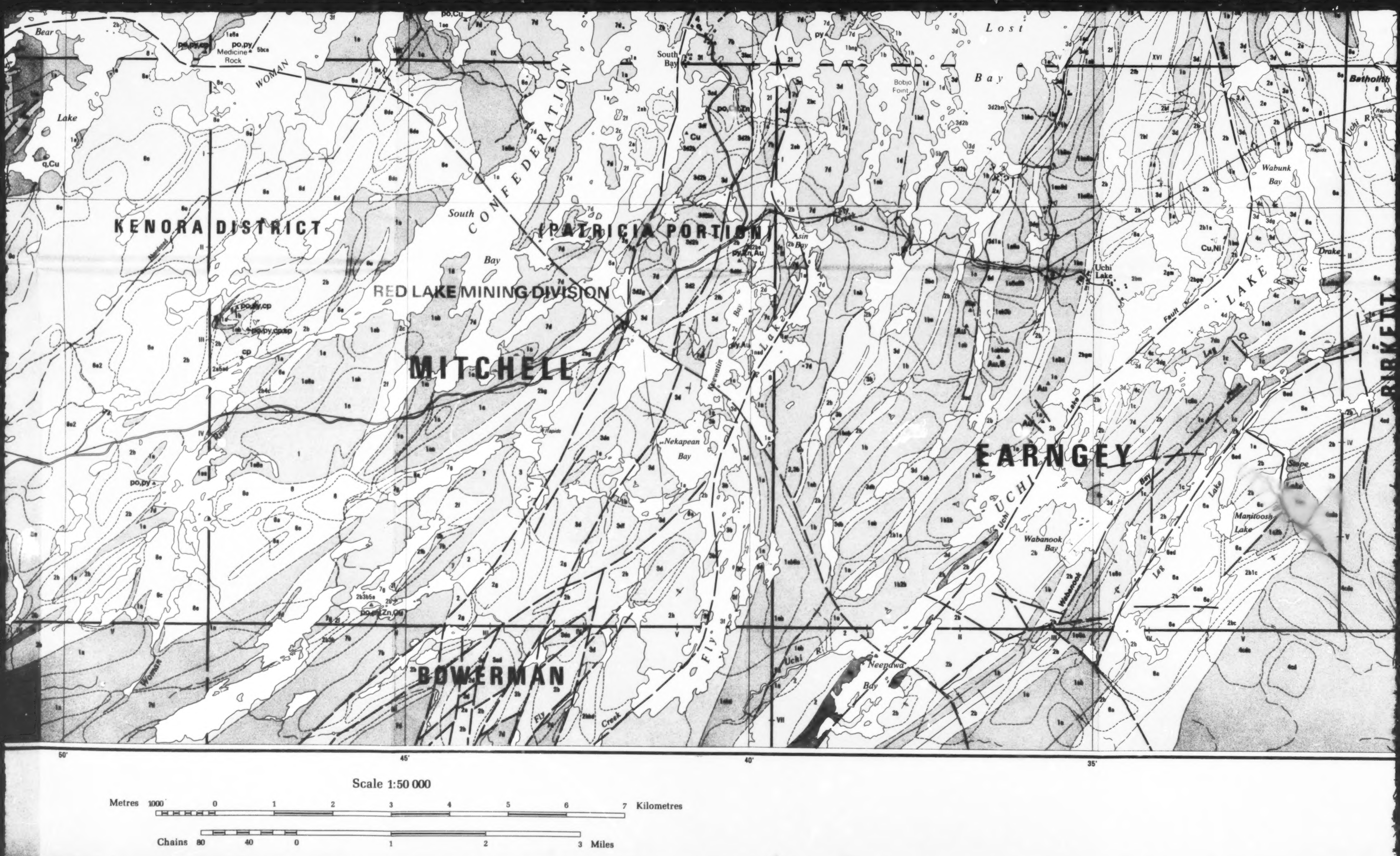
Assessment files, Ministry of Natural Resources, Red Lake and Toronto offices.

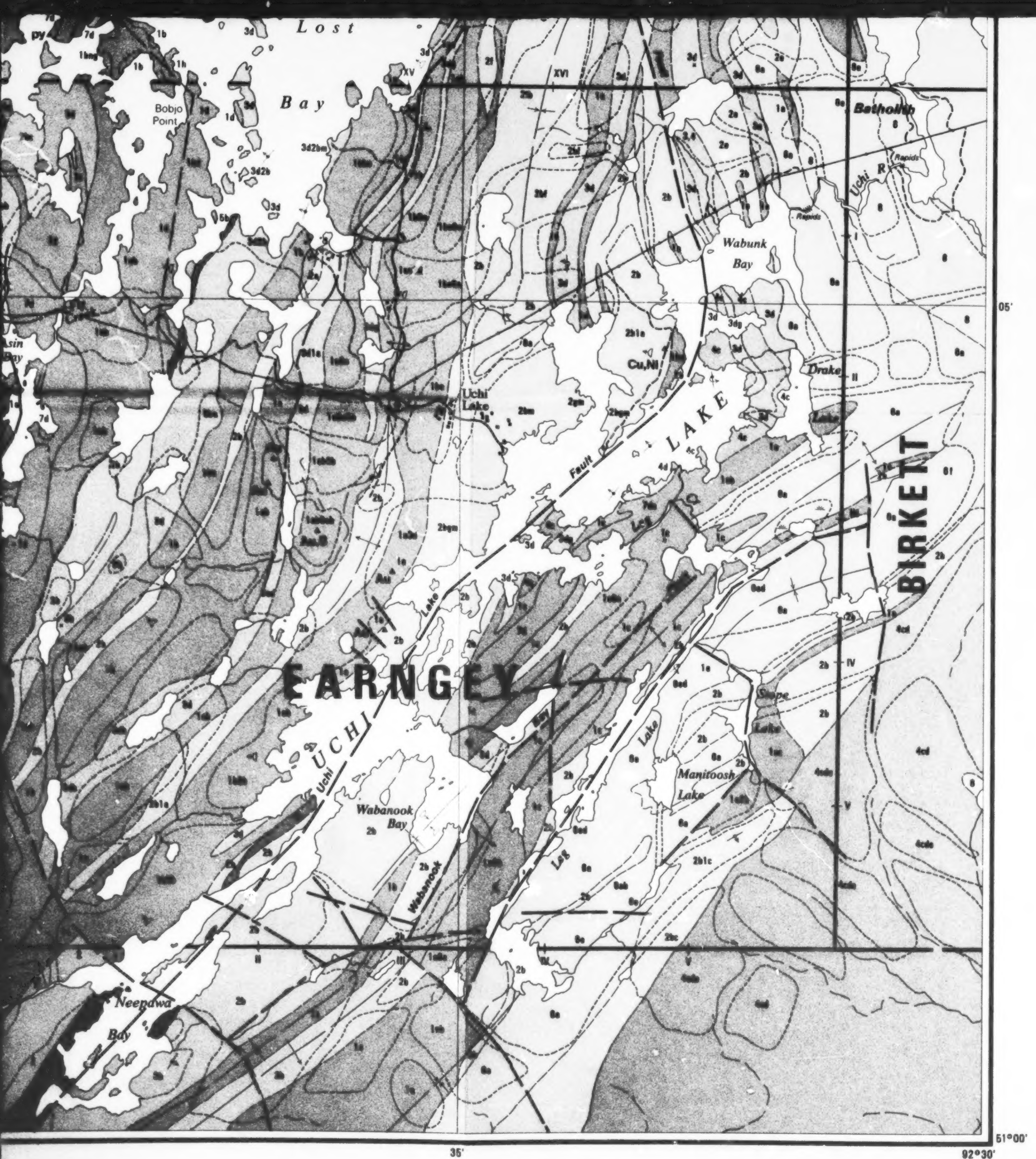
Cartography by P.A. Wisbey and assistants, Surveys and Mapping Branch, 1984.

Topography derived from Forest Resources Inventory maps, Surveys and Mapping Branch, with additional information by P.C. Thurston.

Magnetic declination in the area was approximately 5° 15′ East, 1976.


KNOTT
MITCHELL
BELANGER
BOWERMAN
KENORA DISTRICT
PATRICIA P
RED LAKE MINING DIVISION
CONFEDERATION
Bear Lake
Little Bear Lake
Bear Lake Fault
Woman River
WOMAN
Corless Creek
South Bay
Medicine Rock
Snakeweed Lake
Fredart Cr
Fly Creek
Rapids
Dam
po,py,cp
q,Ag,Cu
Pb,py
cp
Cu,Ag
q,Cu
po,cp
po,py
po,py,cp,sp
po,py,Zn,Cu
po,Cu
LXXI
LXX
LXVIII
LXVII
LXV
05'
51°00'
93°00'
55'
50'
45'
Scale 1:50 000
Metres 1000 0 1 2 3 4 5 6 7 Kilometr
Chains 80 40 0 1 2 3 Miles


KENORA DISTRICT
(PATRICIA PORTION)
RED LAKE MINING DIVISION
CONFEDERATION
MITCHELL
EARNGEY
BOWERMAN
BIRKETT
Bear
Woman
Lake
Medicine Rock
South Bay
Lost
Bay
Bobjo Point
Batholith
Wabunk Bay
Drake
Uchi Lake
Uchi R.
Fault
Asin Bay
Fly Creek
Keewatin Bay
Nekapean Bay
Fly Lake
Wabanook Bay
Manitoosh Lake
Slope Lake
Leg Lake
Wabanook
Neepawa Bay
Uchi
Lake
Rapids
po,py,cp
po,Cu
q,Cu
Cu,Ni
py,Zn,Au
Au
cp
50'
45'
40'
35'
Scale 1:50 000
Metres 1000 0 1 2 3 4 5 6 7 Kilometres
Chains 80 40 0 1 2 3 Miles



2b Tuffs.
2c Porphyritic flows.
2d Pillowed flows.
2e Spherulitic flows, tuffs.
2f Tuff-breccia, pyroclastic breccia.
2g Tuff, lapilli-tuff.
2h Chlorite-sericite schist, biotite-chlorite-sericite schist.
2j Thin-bedded units.
2k Medium-bedded units.
2m Thick-bedded units.

MAFIC METAVOLCANICS[b]

1 Unsubdivided.
1a Massive flows.
1b Pillowed flows.
1c Porphyritic flows.
1d Variolitic flows.
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1h Pillow breccia, hyaloclastic rocks.
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1m Pyroclastic rocks.
1n Autoclastic breccia.

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Bedding, top (arrow) from grain gradation; (inclined, vertical, overturned).

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Lava flow; top (arrow) from pillows shape and packing.

Geological boundary, position interpreted.

Geological boundary, deduced from geophysics.

— — *Lineament or fault.*

Anticline, syncline, with plunge.

Vein.

○ *Past producing mine.*

▲ *Mineral occurrence.*

305 silver

Little Long Lac Gold Mines Ltd. (Uchi Mine) 114,467 oz. gold, 14,345 oz. silver

Selco Mining Corp. Ltd. operated a copper-zinc-silver mine at South Bay of Confederation Lake from 1970 to 1981, producing 68519 tons copper concentrate, 226,287 tons zinc concentrate and 156,212 oz. silver from 1,637,948 tons or ore.

Gold occurrences are numerous, particularly associated with the minor cycles of Cycle II east of Lost Bay of Confederation Lake, but as well, several occurrences are found along Narrow Lake in Cycle II basalt on the west limb of the fold. There are several gold occurrences described in various parts of Cycle II on the west limit of the fold (Map 2428). Base-metal occurrences of note occur south of the South Bay Mine in Cycle III volcanic rocks.

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Topography derived from Forest Resources Inventory maps, Surveys and Mapping Branch, with additional information by P.C. Thurston.

Magnetic declination in the area was approximately 5° 15′ East, 1976.

Parts of this publication may be quoted if credit is given. It is recommended that reference to this map be made in the following form:

Thurston, P.C.
1984: Confederation Lake; Ontario Geological Survey, Map 2498, Precambrian Geology Series, scale 1:50 000, geology 1975-6.

METAL AND MINERAL REFERENCE

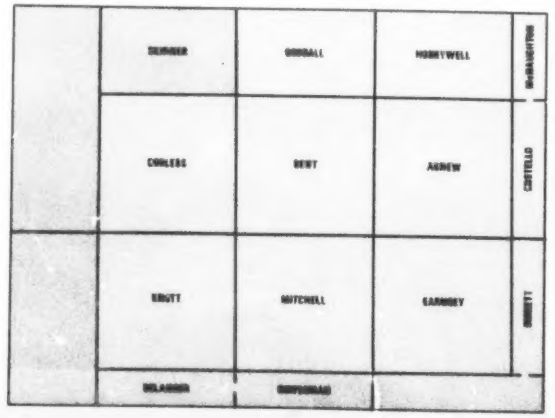
asb	*Asbestos.*	**Ni**	*Nickel.*
Ag	*Silver.*	**Pb**	*Lead.*
Au	*Gold.*	**po**	*Pyrrhotite.*
cp	*Chalcopyrite.*	**py**	*Pyrite.*
Cu	*Copper.*	**q**	*Quartz.*
mag	*Magnetite.*	**sp**	*Sphalerite.*
Mo	*Molybdenum.*	**Zn**	*Zinc.*

PAST PRODUCING MINES

1	*Hudson-Patricia Gold Mines Ltd.**	Au,Ag
2	*Little Long Lac Mines Ltd. (Uchi Mine)*	Au,Ag
3	*Northgate Exploration Ltd., (J-M Consolidated Mine)*	Au,Ag
4	*Selco Mining Corp. Ltd., (South Bay Mine)*	Zn,Cu,Ag

All past producers regardless of the value of metal produced, are listed and shown on the map.

**Property currently owned by M.F. Blue.*



GEOLOGICAL MAP COVERAGE

Detailed mapping: scales 1" to ¼ mile, 1" to ½ mile.

▨ *Reconnaissance mapping: scale 1" to 2 miles.*

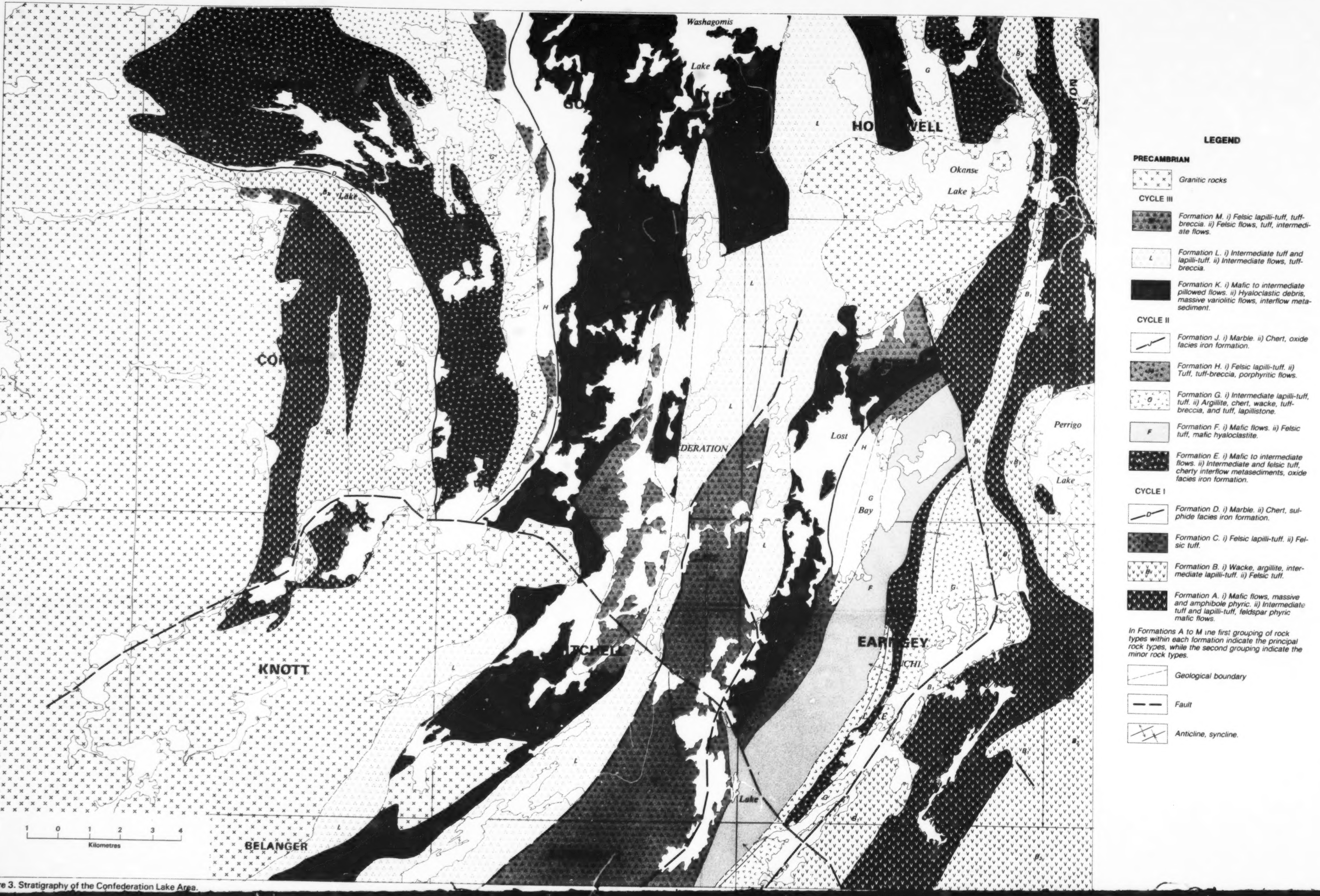

Washagomis
Lake
Okanse
Lake
Perrigo
Lake
Lost
Bay
Lake
KNOTT
BELANGER
EDERATION
TCHELL
1 0 1 2 3 4
Kilometres
LEGEND
PRECAMBRIAN
Granitic rocks
CYCLE III
Formation M. i) Felsic lapilli-tuff, tuff-breccia. ii) Felsic flows, tuff, intermediate flows.
Formation L. i) Intermediate tuff and lapilli-tuff. ii) Intermediate flows, tuff-breccia.
Formation K. i) Mafic to intermediate pillowed flows. ii) Hyaloclastic debris, massive variolitic flows, interflow metasediment.
CYCLE II
Formation J. i) Marble. ii) Chert, oxide facies iron formation.
Formation H. i) Felsic lapilli-tuff. ii) Tuff, tuff-breccia, porphyritic flows.
Formation G. i) Intermediate lapilli-tuff, tuff. ii) Argillite, chert, wacke, tuff-breccia, and tuff, lapillistone.
Formation F. i) Mafic flows. ii) Felsic tuff, mafic hyaloclastite.
Formation E. i) Mafic to intermediate flows. ii) Intermediate and felsic tuff, cherty interflow metasediments, oxide facies iron formation.
CYCLE I
Formation D. i) Marble. ii) Chert, sulphide facies iron formation.
Formation C. i) Felsic lapilli-tuff. ii) Felsic tuff.
Formation B. i) Wacke, argillite, intermediate lapilli-tuff. ii) Felsic tuff.
Formation A. i) Mafic flows, massive and amphibole phyric. ii) Intermediate tuff and lapilli-tuff, feldspar phyric mafic flows.
In Formations A to M the first grouping of rock types within each formation indicate the principal rock types, while the second grouping indicate the minor rock types.
Geological boundary
Fault
Anticline, syncline.

Figure 3. Stratigraphy of the Confederation Lake Area.

Confederation Lake Report
Chart 'A'
Figures 3, 22, and 23

LEGEND

MBRIAN

☒ *Granitic rocks*

LE III

■ *Formation M. i) Felsic lapilli-tuff, tuff-breccia. ii) Felsic flows, tuff, intermediate flows.*

△ *Formation L. i) Intermediate tuff and lapilli-tuff. ii) Intermediate flows, tuff-breccia.*

■ *Formation K. i) Mafic to intermediate pillowed flows. ii) Hyaloclastic debris, massive variolitic flows, interflow metasediment.*

LE II

☐ *Formation J. i) Marble. ii) Chert, oxide facies iron formation.*

■ *Formation H. i) Felsic lapilli-tuff. ii) Tuff, tuff-breccia, porphyritic flows.*

☐ *Formation G. i) Intermediate lapilli-tuff, tuff. ii) Argillite, chert, wacke, tuff-breccia, and tuff, lapillistone.*

▨ *Formation F. i) Mafic flows. ii) Felsic tuff, mafic hyaloclastite.*

■ *Formation E. i) Mafic to intermediate flows. ii) Intermediate and felsic tuff, cherty interflow metasediments, oxide facies iron formation.*

LE I

☐ *Formation D. i) Marble. ii) Chert, sulphide facies iron formation.*

■ *Formation C. i) Felsic lapilli-tuff. ii) Felsic tuff.*

☐ *Formation B. i) Wacke, argillite, intermediate lapilli-tuff. ii) Felsic tuff.*

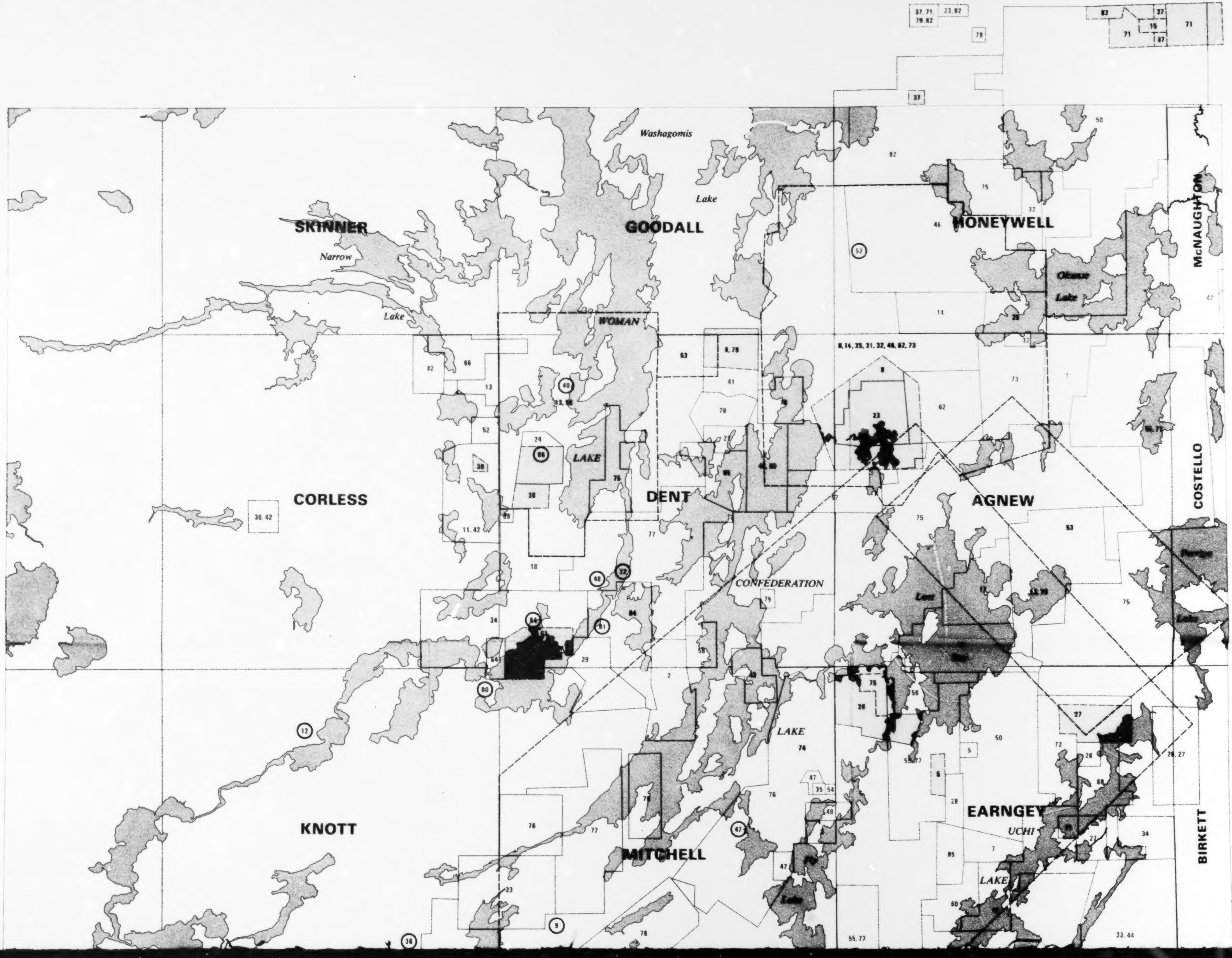
■ *Formation A. i) Mafic flows, massive and amphibole phyric. ii) Intermediate tuff and lapilli-tuff, feldspar phyric mafic flows.*

ations A to M ıne first grouping of rock ithin each formation indicate the principal es, while the second grouping indicate the ck types.

☐ *Geological boundary*

☐ *Fault*

☐ *Anticline, syncline.*



Washagomis
Lake
SKINNER
Narrow
Lake
GOODALL
WOMAN
LAKE
HONEYWELL
Okanze
Lake
McNAUGHTON
CORLESS
DENT
AGNEW
COSTELLO
CONFEDERATION
LAKE
KNOTT
MITCHELL
EARNGEY
UCHI
LAKE
BIRKETT

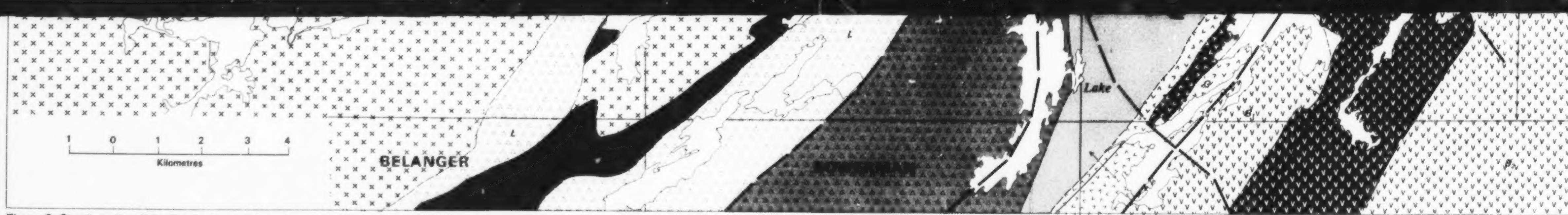
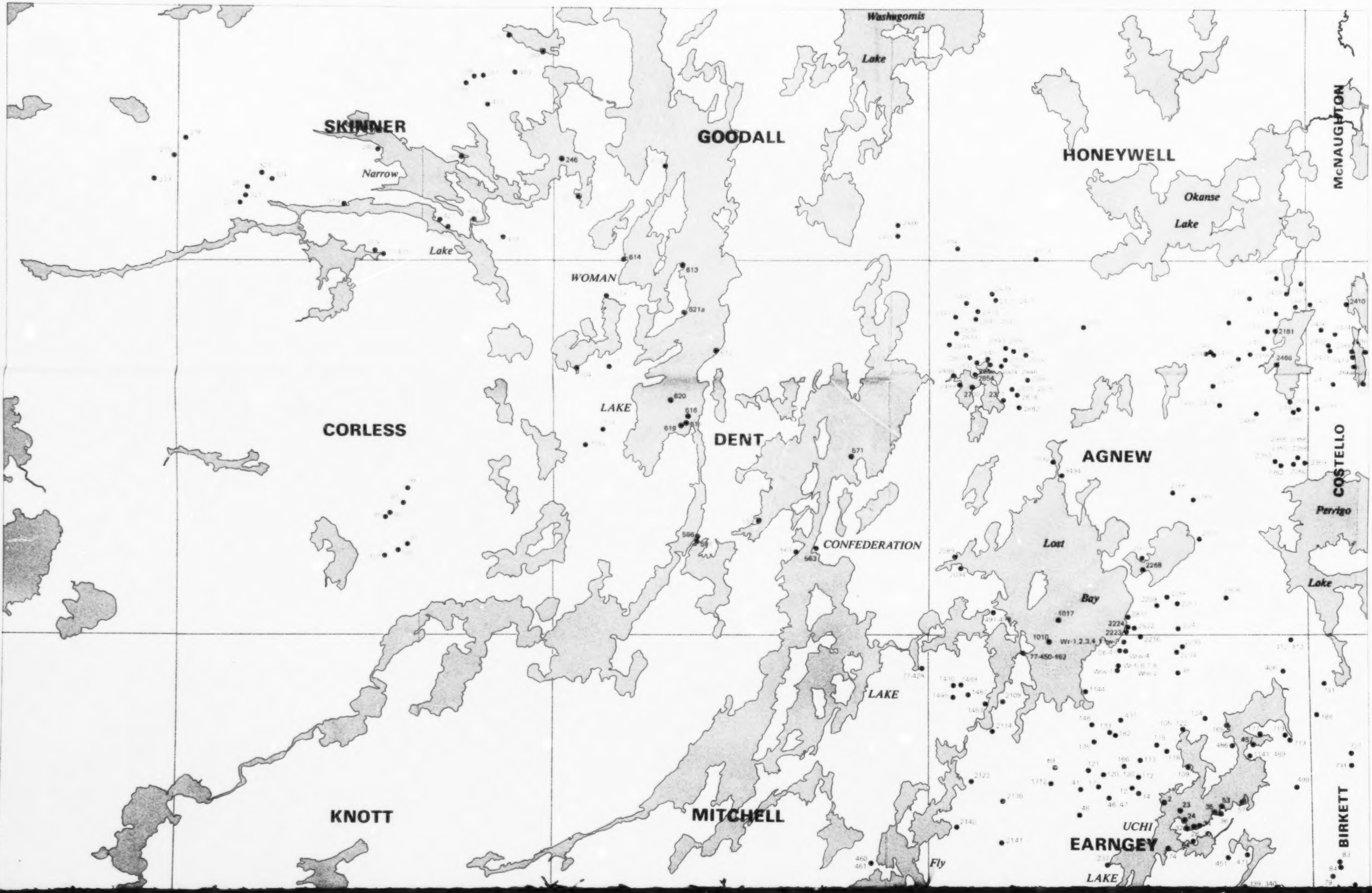

1 0 1 2 3 4
Kilometres
BELANGER
Lake

Figure 3. Stratigraphy of the Confederation Lake Area.

SMC 15318


Washagomis
Lake
SKINNER
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Okanse
Lake
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LAKE
CORLESS
DENT
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COSTELLO
Perrigo
Lake
CONFEDERATION
Lost
Bay
LAKE
KNOTT
MITCHELL
EARNGEY
UCHI
LAKE
Fly
BIRKETT

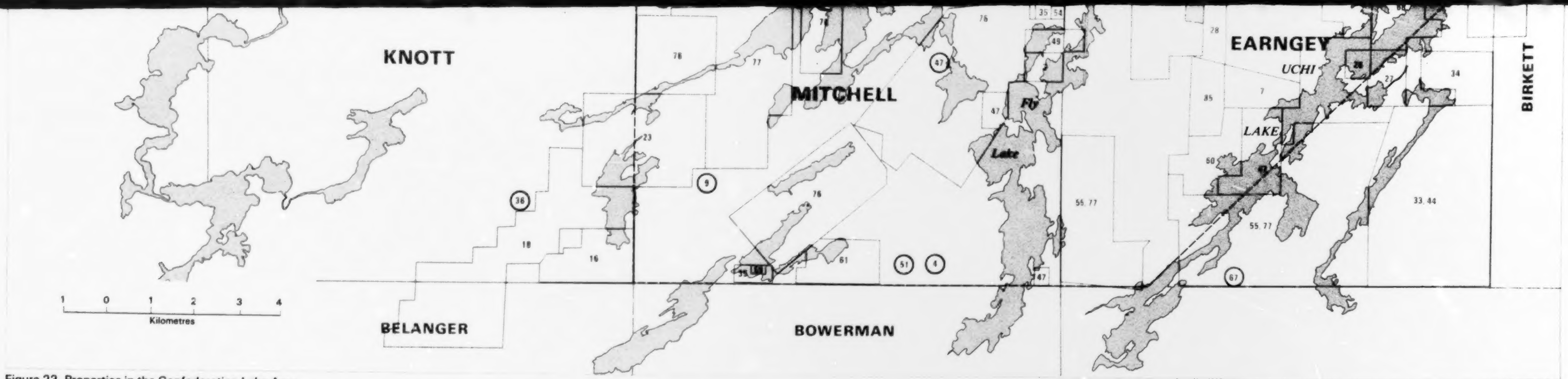

Figure 23. Properties in the Confederation Lake Area.

SMC 15338

ASSESSMENT WORK IN THE CONFEDERATION LAKE AREA

No*	Name	Assay/ Geochemical	Geological	Diamond Drilling	Ground Magnetometer	Ground EM	Airborne Magnetometer	Airborne EM	Airborne Radiometric	Toronto File Number	Township
1	Alchib Developments Ltd.										Agnew
2	Alexander Red Lake Mines Ltd.	1969	1969	1970	1969	1969				63.2738	Dent Mitchell
3	Arrowsmith, W.C.			1968							Mitchell
4	Beaudoin, A.										Mitchell
5	Bergeron, Mrs. K., (former Berrigan property)	1939									Earngey
6	Blue, M.F., (former Hudson-Patrica Gold Mines Ltd. property–St. Joseph Explorations Ltd. option)				1975	1975				2.1785	Dent Goodall
7	Bohme, J.D.S., (Tashota-Nipigon Mines Ltd. option)		1968	1970	1968, 9	1969				63.2436	Earngey
8	Boylen, M.J. and Assocs.						1969	1969		63.2708	Agnew Dent
9	Brannan, R.										Mitchell
10	Bretton Mines Ltd.										Dent
11	Brown, H.H.										Corless
12	Cameron, D.R.										Knott
13	Canex Aerial Exploration Ltd.										Dent Goodall Corless
14	Captain Mines Ltd.										Honeywell
15	Charron, R.T.					1975				2.1771	Honeywell
16	Cochenour Explorations Ltd.		1969			1969				63.2742	Knott
17	Colleen Copper Mines Ltd., (G. Leliever property?)				1969	1969				63.2690	Agnew
18	Conwest Exploration Co. Ltd.				1969	1969				63.2606 63.2760	Knott Belanger
19	Copperville Mining Corp. Ltd., (M. Watts property?)				1969	1969				63.2690	Agnew Earngey
20	Darrell Gold Mines Ltd.		1938								Earngey
21	Davies, R.W.										Dent
22	Dimitrieff, G.										Dent
23	Dome Exploration (Canada) Ltd.						1969	1969		63.2680 63.2682	Mitchell Honeywell Agnew Knott
24	Dougron Gold Mines Ltd.			1948	1948					63.166	Dent
25	Eastmont Larder Lake Gold Mines Ltd.						1970	1970		63.2708	Honeywell Agnew
26	Falconbridge Nickel Mines Ltd.				1969, 70	1969, 70				63.2722	Birkett Earngey
27	Falconbridge Nickel Mines Ltd.						1969	1969		2.346	Earngey Birkett
28	Geisler, R.A.										Earngey
29	Gloster, M.E., (Selco Mining Corp. Ltd. option)			1970	1970	1970				63.3032	Dent Mitchell
30	Goettler, G.										Corless
31	Gordon, D.W.						1969	1969	1969	63.2708	Honeywell Agnew Dent Goodall
32	Grandroy Mines Ltd.						1969	1969	1969	63.2708	Honeywell Agnew
33	Gripp Lake Mines Ltd.										Earngey
34	Hanna Gold Mines Ltd.				1970	1970				63.2842 63.2841	Earngey Dent Corless
35	Heath Gold Mines Ltd.	1951	1951	1951							Mitchell
36	Hemming, G.										Knott
37	Hlava, M.			1973							Honeywell
38	Hobbs, L.G., (Canex Aerial Exploration Ltd.		1970	1970	1970	1970	1969	1969	1969	63.2770 2.516	Dent
47	Kerr Addison Mines Ltd.			1975, 6	1975	1975				2.2000	Earngey Mitchell
48	Kukoraitis, V.										Dent
49	Lee, N.										Earngey Mitchell
50	Long Lac Mineral Explorations Ltd.						1968, 9	1968, 9	1968, 9	63.2704 63.2733	Earngey Honeywell McNaughton
51	Martin, A.										Mitchell
52	McIntyre Mines Ltd.				1975	1975				63.2035	Honeywell Corless
53	Midland Nickel Corp. Ltd., (Canex Aerial Exploration Ltd. option)		1970				1969	1969		63.2720 63.2672	Earngey Dent Agnew Costello
54	Murphy, J.A., (Selco Mining Corp. Ltd., Columbière option)				1971	1970				2.229 2.833	Mitchell
55	New Hosco Mines Ltd.										Earngey Agnew Costello
56	New York Oils Ltd.										Earngey Agnew
57	Noranda Exploration Co.				1969	1969				63.2737	Dent Agnew
58	Noranda Exploration Co.				1972	1972				2.835	Dent
59	Norite Explorations Ltd.			1964							Mitchell
60	Northgate Exploration Ltd.	1959		1959, 61, 73							Earngey
61	North Rock Explorations Ltd.				1969	1969				63.2479	Mitchell
62	Nudulama Mines Ltd.						1969	1969		63.2708	Agnew Honeywell
63	Ontario Woman Lake Gold Mines Ltd.		1934	1934							Dent Mitchell
64	Patino Mining Corp., The										Dent Mitchell Corless Knott
65	Patricia Dent Gold Mines Ltd.		1935								Dent
66	Phelps Dodge Corp. of Canada Ltd.			1968						10	Dent Corless
67	Picarium Gold Mines Ltd.										Earngey
68	Polkholm, H., (former Campbell Island Mines & Explorations Ltd. property)		1956, 7	1955, 6,							Earngey
69	Roby, G.										Dent
70	Roby, P.										Dent
71	Ronda Copper Mines Ltd.		1974	1976		1976				2.2079 2.1554	McNaughton Honeywell
72	Salem Exploration Ltd.		1966				1966			63.2047	Earngey
73	Satellite Metal Mines Ltd.						1969	1969		63.2708	Agnew Honeywell
74	Selco Mining Corp. Ltd.						1969	1969			Dent Mitchell Earngey Agnew
75	Selco Mining Corp. Ltd.			1968-70, 2, 4, 6							Earngey Agnew Dent Honeywell
76	Selco Mining Corp. Ltd.	1972		1968-70, 5							Mitchell
77	Sheridan Geophysics Ltd.				1969, 70	1969, 70				2.20 2.21 2.22 2.23 2.24 2.44	Earngey Dent Mitchell Costello Agnew
78	Shilo Mines Ltd.		1973							2.1441	Dent
79	St. Joseph Explorations Ltd.		1975, 6	1974, 6	1973, 5, 6	1973, 5, 6				2.2077 2.1350 2.1441 2.2132	Honeywell Dent Goodall

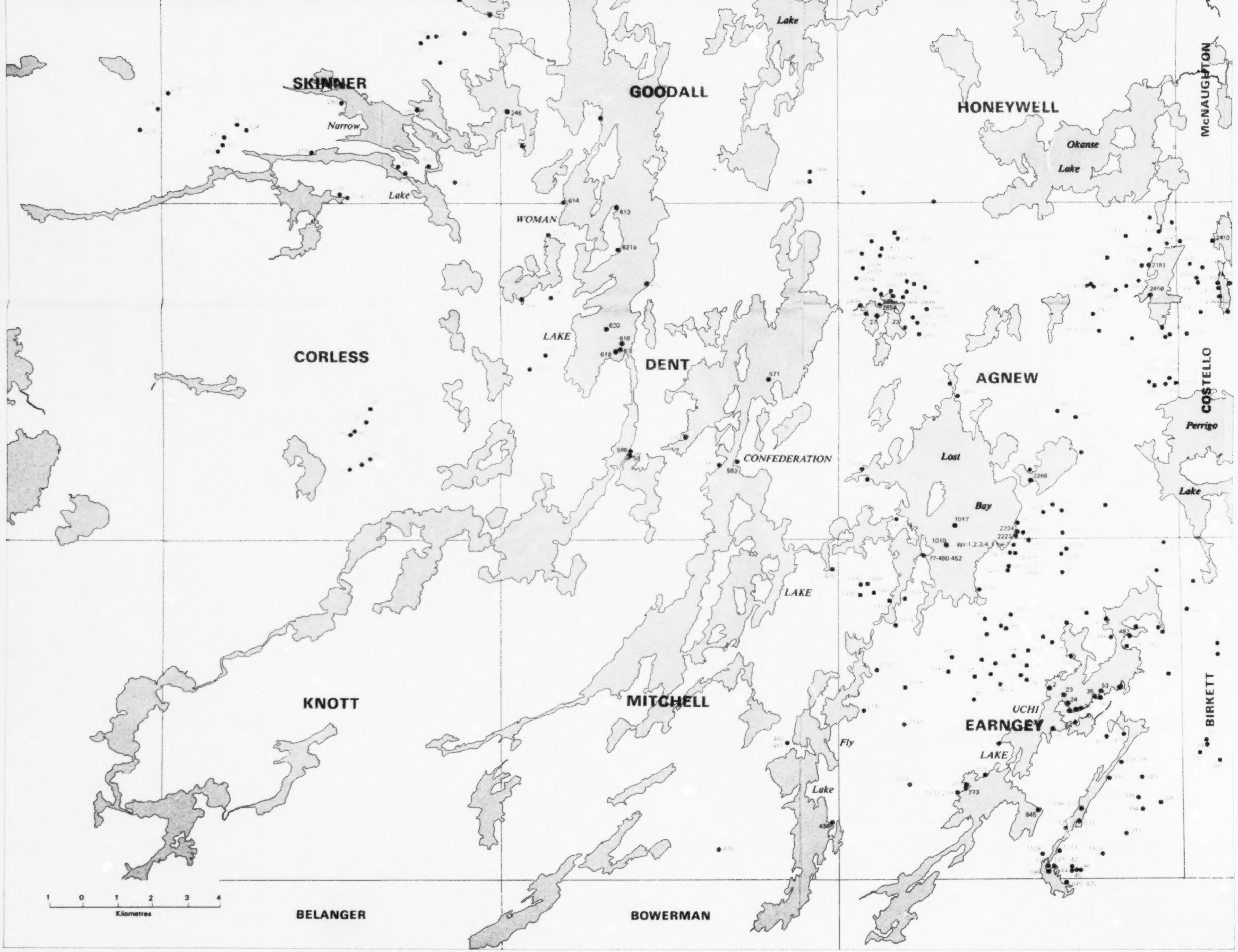
SKINNER
Narrow
Lake
GOODALL
Lake
HONEYWELL
Okanse
Lake
McNAUGHTON
WOMAN
LAKE
CORLESS
DENT
AGNEW
COSTELLO
Perrigo
Lake
CONFEDERATION
Lost
Bay
LAKE
KNOTT
MITCHELL
Fly
Lake
UCHI
EARNGEY
LAKE
BIRKETT
BELANGER
BOWERMAN
1 0 1 2 3 4
Kilometres

Figure 22. Location of thin section specimens.

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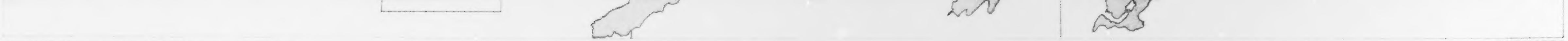

Figure 23. Properties in the Confederation Lake Area.

SMC 15338

ASSESSMENT WORK IN THE CONFEDERATION LAKE AREA

No*	Name	Assay/ Geochemical	Geological	Diamond Drilling	Ground Magnetometer	Ground EM	Airborne Magnetometer	Airborne EM	Airborne Radiometric	Toronto File Number	Township
1	Alchib Developments Ltd.										Agnew
2	Alexander Red Lake Mines Ltd.	1969	1969	1970	1969	1969				63.2738	Dent Mitchell
3	Arrowsmith, W.C.			1968							Mitchell
4	Beaudoin, A.										Mitchell
5	Bergeron, Mrs. K., (former Berrigan property)	1939									Earngey
6	Blue, M.F., (former Hudson-Patrica Gold Mines Ltd. property–St. Joseph Explorations Ltd. option)				1975	1975				2.1785	Dent Goodall
7	Bohme, J.D.S., (Tashota-Nipigon Mines Ltd. option)		1968	1970	1968, 9	1969				63.2436	Earngey
8	Boylen, M.J. and Assocs.						1969	1969		63.2708	Agnew Dent
9	Brannan, R.										Mitchell
10	Bretton Mines Ltd.										Dent
11	Brown, H.H.										Corless
12	Cameron, D.R.										Knott
13	Canex Aerial Exploration Ltd.										Dent Goodall Corless
14	Captain Mines Ltd.										Honeywell
15	Charron, R.T.					1975				2.1771	Honeywell
16	Cochenour Explorations Ltd.		1969			1969				63.2742	Knott
17	Colleen Copper Mines Ltd., (G. Leliever property?)				1969	1969				63.2690	Agnew
18	Conwest Exploration Co. Ltd.				1969	1969				63.2606 63.2760	Knott Belanger
19	Copperville Mining Corp. Ltd., (M. Watts property?)				1969	1969				63.2690	Agnew Earngey
20	Darrell Gold Mines Ltd.		1938								Earngey
21	Davies, R.W.										Dent
22	Dimitrieff, G.										Dent
23	Dome Exploration (Canada) Ltd.						1969	1969		63.2680 63.2682	Mitchell Honeywell Agnew Knott
24	Dougron Gold Mines Ltd.			1948	1948					63.166	Dent
25	Eastmont Larder Lake Gold Mines Ltd.						1970	1970		63.2708	Honeywell Agnew
26	Falconbridge Nickel Mines Ltd.				1969, 70	1969, 70				63.2722	Birkett Earngey
27	Falconbridge Nickel Mines Ltd.						1969	1969		2.346	Earngey Birkett
28	Geisler, R.A.										Earngey
29	Gloster, M.E., (Selco Mining Corp. Ltd. option)			1970	1970	1970				63.3032	Dent Mitchell
30	Goettler, G.										Corless
31	Gordon, D.W.						1969	1969	1969	63.2708	Honeywell Agnew Dent Goodall
32	Grandroy Mines Ltd.						1969	1969	1969	63.2708	Honeywell Agnew
33	Gripp Lake Mines Ltd.										Earngey
34	Hanna Gold Mines Ltd.				1970	1970				63.2842 63.2841	Earngey Dent Corless
35	Heath Gold Mines Ltd.	1951	1951	1951							Mitchell
36	Hemming, G.										Knott
37	Hlava, M.			1973							Honeywell
38	Hobbs, L.G., (Canex Aerial Exploration Ltd. –Dalhousie Oil Co. Ltd. option)		1970	1970	1970	1970	1969	1969	1969	63.2770 2.516 63.2707	Dent
39	Hodgson, J.										Corless Dent
40	Hood, W.C.										Dent
41	Hudson-Patricia Gold Mines Ltd.	1935	1935								Dent Goodall
42	Huston, C.C. and Assocs.				1970	1970	1969	1969	1969	63.2482 2.201 63.2546	Corless McNaughton
43	Huston, C.D.	1976			1974	1974				2.1939	Dent Mitchell
44	Jellicoe Mines Ltd.										Earngey
45	Juby, M.L.										Dent
46	Kennedy, C.S.						1969	1969		63.2708	Honeywell Agnew
47	Kerr Addison Mines Ltd.			1975, 6	1975	1975				2.2000	Earngey Mitchell
48	Kukoraitis, V.										Dent
49	Lee, N.										Earngey Mitchell
50	Long Lac Mineral Explorations Ltd.						1968, 9	1968, 9	1968, 9	63.2704 63.2733	Earngey Honeywell McNaughton
51	Martin, A.										Mitchell
52	McIntyre Mines Ltd.				1975	1975				63.2035	Honeywell Corless
53	Midland Nickel Corp. Ltd., (Canex Aerial Exploration Ltd. option)		1970				1969	1969		63.2720 63.2672	Earngey Dent Agnew Costello
54	Murphy, J.A., (Selco Mining Corp. Ltd., Columbière option)				1971	1970				2.229 2.833	Mitchell
55	New Hosco Mines Ltd.										Earngey Agnew Costello
56	New York Oils Ltd.										Earngey Agnew
57	Noranda Exploration Co.				1969	1969				63.2737	Dent Agnew
58	Noranda Exploration Co.				1972	1972				2.835	Dent
59	Norite Explorations Ltd.			1964							Mitchell
60	Northgate Exploration Ltd.	1959		1959, 61, 73							Earngey
61	North Rock Explorations Ltd.				1969	1969				63.2479	Mitchell
62	Nudulama Mines Ltd.						1969	1969		63.2708	Agnew Honeywell
63	Ontario Woman Lake Gold Mines Ltd.		1934	1934							Dent Mitchell
64	Patino Mining Corp., The										Dent Mitchell Corless Knott
65	Patricia Dent Gold Mines Ltd.		1935								Dent
66	Phelps Dodge Corp. of Canada Ltd.			1968						10	Dent Corless
67	Picanum Gold Mines Ltd.										Earngey
68	Polkholm, H., (former Campbell Island Mines & Explorations Ltd. property)		1956, 7	1955, 6,							Earngey
69	Roby, G.										Dent
70	Roby, P.										Dent
71	Ronda Copper Mines Ltd.		1974	1976		1976				2.2079 2.1554	McNaughton Honeywell
72	Salem Exploration Ltd.		1966				1966			63.2047	Earngey
73	Satellite Metal Mines Ltd.						1969	1969		63.2708	Agnew Honeywell
74	Selco Mining Corp. Ltd.						1969	1969			Dent Mitchell Earngey Agnew
75	Selco Mining Corp. Ltd.			1968-70, 2, 4, 6							Earngey Agnew Dent Honeywell
76	Selco Mining Corp. Ltd.	1972		1968-70, 5							Mitchell
77	Sheridan Geophysics Ltd.				1969, 70	1969, 70				2.20 2.21 2.22 2.23 2.24 2.44	Earngey Dent Mitchell Costello Agnew
78	Shilo Mines Ltd.		1973							2.1441	Dent
79	St. Joseph Explorations Ltd.		1975, 6	1974, 6	1973, 5, 6	1973, 5, 6				2.2077 2.1350 2.1441 2.2132	Honeywell Dent Goodall
80	Teal, H.G.										Knott
81	Thompson, D.M.										Dent
82	Vanco Exploration of Ontario Ltd.		1969	1971	1969, 71	1969, 71	1969	1969		2.400 63.2702 63.2703 63.2716 63.2663	Corless Honeywell
83	Williams, C.										Honeywell
84	Williams, D.										Dent
85	Woco Gold Developments Ltd.	1939									Earngey
86	Woman Lake Goldfields Development Ltd.	1928									Dent

*For location of property, see Figure 23.
Additional information available in assessment files at the Resident Geologist's Office, Red Lake.
Information current to 31st December 1976.